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## ORIGINAL ARTICLES.

### I.—The Structure of Glaciers.

By R. M. Deeley, F.G.S.

In August, 1841, Professor J. D. Forbes, in company with Professor Agassiz and Mr. Heath, spent some time upon the Lower Glacier of the Aar, and Forbes states that it was then for the first time that he noticed the veined or ribboned structure of glaciers. Although the description given in the communication he made to the Royal Society of Edinburgh in December of the same year is most interesting, he does not state clearly how the structure is related to the glacier grains of which the ice streams are built up.

During the several visits I have paid to Switzerland for the purpose of studying the structure of glacier ice the relationship between the form and size of the ice grains and the superficial effects produced by their weathering have been carefully noted.

Except at high altitudes the granular structure of the ice can only be properly studied in the ice caves which have been excavated for the attraction of tourists. At low levels the glacier surface is much disintegrated by the warm air and sun, and its appearance will be found to depend upon the size and shape of the glacier grains or the inclusion of air bubbles. Although Forbes frequently speaks of the veined or ribboned structure as though they were one and the same thing, the ribboning is rather a feature of the glacier surface when the veining is well developed.

*Stratification.*—In cases where the vertical unweathered faces of glaciers are exposed, such as those which are formed by the breaking away of the ice of hanging glaciers, the ice is seen to be horizontally stratified, the white layers being those portions of the ice which contain an excess of air bubbles imprisoned in the mass.

If the surface of the *névé* were always in a powdery loose condition at the surface it is likely that, as the mass became consolidated, the air would be almost wholly expressed and very blue clear ice would be formed. Glaciers, where clean vertical surfaces are exposed, vary much as regards blueness, the air bubbles where they are numerous making the ice appear more or less white in appearance.

The transformation of the snow into ice is the result of the slow growth of some crystals and the disappearance of others, and to the viscosity of the crystals in a direction at right angles to their optic

axes. The consolidation must also be facilitated by the slow melting of the points of contact of granule with granule, due to the lower melting-point of the more stressed portions. Time is therefore an important consideration, as also is temperature, in the process of the consolidation of snow consisting of a great number of ice spicules, etc., into glacier ice consisting of a much smaller number of large crystalline grains.

The Antarctic Great Barrier, Professor T. W. E. David says, is composed of highly compacted snow rather than glacier ice. From measurements of the snowfall on it and the rate of flow he concludes that the ice at the depth of 900 feet at the Barrier face is only 900 years old. As the visible face is only about 120 feet high the oldest ice seen is therefore 120 years. To what extent the snow has really been converted into glacier grains we are as yet unable to say. It, however, clearly contains a very large number of air bubbles which give it the appearance of compacted snow and much reduce its density.

In most instances the *névé* surface is melted by the sun or warm air. In this way more or less impervious layers of ice are formed, which prevent the escape of the imprisoned air.

One of the first impressions produced on the mind on entering an ice cave is the solidity and blueness of the ice. One, however, soon notices white discontinuous layers, generally roughly parallel with the glacier bed, but much twisted and broken. These are the stratifications produced in the *névé* by the imprisoning of air bubbles.

Although the mass of the ice consists of glacier grains of all sizes and shapes the bubbles bear no relationship to either the size or the arrangement of the grains. The great majority of the bubbles are enclosed in the ice granules. Only occasionally are they seen at the interfaces. It would seem that as the crystals grow or decrease in size and the positions of the interfaces alter the bubbles are not displaced.

It is only at great elevations, where ice falls from hanging glaciers and thus exposes fresh clean surfaces, or in ice caves that I have seen the regular stratification due to imprisoned air. In the *névé* it is very clearly marked, but lower down in the glacier the differential motion, the opening and closing of crevasses, etc., give rise to great distortion of the white layers.

*Veining.*—A careful examination of the walls of an ice cave will reveal the fact that the glacier consists of an agglomeration of ice granules, the outlines of the granules being clearly defined by the delicate lines on their surfaces or the melting along the lines of contact. If a thin piece of notepaper be placed against the ice and the surface of the paper be rubbed with a pencil a rough copy of the surface markings is obtained. The granules vary in size very much, the glacier being composed of beds of granules of varying coarseness.

In a paper communicated to the Geological Magazine by Mr. G. Fletcher and the author we say "the veining resulted partly from the arrangement of the crystal grains and partly from a variation in the shape of the grains and partly from variations in their dimensions".

Except in ice caves, the very deep portions of crevasses, or beneath the moraines or large stones on the surfaces of the lower glaciers the ice is seldom seen in its blue compact condition. The effect of the sun upon the surface of a glacier is to break up the compact ice into loose crystalline granules. The principal effect of the sun is therefore to separate the granules by melting them at their interfaces. It is not necessary to postulate the presence of sodium salts in the ice to account for the rapid melting at the interfaces. At the interfaces the molecules are in an abnormal condition of strain, and are more easily set free (melted) than are those in the interior of the granules. Many of the interfaces are the result of slow shear without fracture bringing part of one grain against another, and in such cases there is surely no likelihood of the presence of foreign salts.

When not subjected to severe strains the larger ice granules grow in size at the expense of the small granules, which disappear. Where the strains are great, however, the large granules are broken up into smaller ones again. This breaking up of the granules occurs in layers of more or less considerable thickness in directions parallel with the motion of the glacier, which thus becomes composed of layers of granules of varying coarseness. The heat of the sun shining on the glacier disintegrates the grains, and the smaller these are the whiter the glacier surface appears, and the larger they are the bluer the surface appears. A large transparent bluish crystal, for instance, if broken up will form a white powder. The blue and white veins seen on the surface of a glacier and passing near the sides of the glacier stream almost vertically down the walls of the crevasses, are due to the disintegration of layers of granular ice of varying coarseness. That this is the case I have proved by cutting away the disintegrated white surface until firm blue ice was reached, and by examining the granules below blue and white veins.

*Ribboned structure.*—The veined and the ribboned structures are generally so closely associated that they were dealt with by Forbes as one structure. We will leave Forbes to describe this feature in his own words. "I noticed in some parts of the ice an appearance which I cannot more accurately describe than by calling it ribboned structure, formed by *thin* and delicate blue and bluish-white bands or strata, which appeared to traverse the ice in a vertical direction, or rather which by their opposition formed the entire mass of the ice. The direction of these bands was parallel to the length of the glacier, and of course being vertical they cropped out at the surface . . . Not only did we trace them down the walls of the crevasses by which the glacier is intersected, as far as we could distinctly see, but, coming to a great excavation in the ice, at least 20 feet deep, formed by running water, we found the vertical strata or bands perfectly well defined throughout the whole mass of ice to that depth." It is these vertical strata or bands which run mainly in or near the white veins which I regard as the ribboned structure. Neither these ribbons nor the white and blue veins should be confounded with the stratification of the *névé* due to air bubbles. The ribboned structure, and also the veining when seen near the sides of the glacier, is generally more or less vertical, but in the Mer de Glace, etc., the

structure may be seen to curve round and cross the centre of the glacier, forming great loops directed down-stream. The veining and ribboned structure are nearly parallel with the sides and bottom of the glacier, and where the surface is being rapidly melted the lower horizontal veins near the middle come to the surface and form these loops. Forbes appears to be quite correct when he says "the vertical structure is too close to the original strata of the *névé* to allow of the supposition that these have all of a sudden turned up vertically in some parts of the glacier, and disappeared in the remainder".

In the cave which was made in the lower portion (which has now melted away) of the Upper Grindelwald glacier I have seen the ice built up of more or less regular layers of flat ice granules, the whole appearing like a mass of masonry or ribbons of grains. The shear-planes cutting the granules and giving rise to this ribboning are produced by slow shear without fracture parallel to the direction of flow. This regular structure produced by shear is not commonly seen in ice caves, for they are generally excavated at the ends of glaciers where the rate of distortion is small. Where this masonry-like structure crops out on the glacier it discloses itself as ribboned structure. As before remarked it is generally parallel with the veined structure, and seems to make it more striking. On the Rhone glacier the ribboned structure is shown up by the dirt which settles in the parallel fissures produced by the melting of the ice along the shear-planes. Where streams cut into the ice it is frequently well shown.

Both the veined and ribboned structure will be found most perfectly developed when the glacier is moving rapidly and the internal strains, i.e. rate of distortion, is greatest. When a glacier widens, becomes thin, or for any reason moves slowly, the slow alterations which are constantly taking place in the shape of the grains gradually obliterates the structure. Owing to the motion the structure is also carried to portions lower down the glacier than those where it is being produced, and in crevassed areas the veins and ribboned structure are twisted about in a very striking manner. The time required for the grains to appreciably alter their form and size must be measured in years.

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## II.—On the discovery of Bembridge Limestone Fossils on Creechbarrow Hill, Isle of Purbeck.

By Henry Keeping, Sedgwick Museum, Cambridge.

(PLATE XXXIV.)

WHEN last year I had an opportunity of examining a few rocks and fossils from the limestone of Creechbarrow Hill, which the late Mr. W. H. Hudleston considered of Bagshot age, I at once suspected that they belonged to the Bembridge Limestone. Upon my pointing this out to Professor Hughes he requested me to go down to examine the ground, which I did in November of last year, but I found only the same fossils which Mr. Hudleston had recorded, namely, *Melanopsis* and *Paludina*. On my return to Cambridge I expressed the opinion that better evidence would probably be obtained if a few openings were made here and there, and the Professor arranged that

I should carry out a further examination of the area at a more convenient season. This I have done, and I now offer the results of my further researches.

After getting permission from the owner of the land, G. W. Bond, Esq., and his tenant, Mr. Trent, I commenced by making an opening on the south side, and also spent some time in the pit which Mr. Hudleston had made, but I found only the same fossils as on my last visit. Feeling sure that the limestone must be found at a lower level I opened another pit, about 12 feet long, at the base of the limestone. At one end of this pit I found a reddish marl called by the workmen Cherry Marl, which I refer to the Osborne formation. Few or no fossils are ever found in this marl. At the end nearest the top of the hill we came on the base of the limestone resting on the marls. I recognized the section as exactly similar to that in which the vertebrate remains were found in the Isle of Wight, and examined it carefully. In about ten or twelve minutes I found part of the tooth of a *Palæotherium*. Unfortunately I had only about a yard of this bed exposed, but I feel sure from the character of the deposit that more mammalian remains might be obtained here. I then opened

Diagram Section showing the relation of the Creechbarrow Limestone to the underlying series: *a*, Bembridge Limestone; *b*, Osborne Series; *c*, Upper Headon Series; *d*, Middle ditto; *e*, Lower ditto; *f*, Sands; *g*, Barton Beds; *h*, Bracklesham Beds with lignite; *i*, Bagshot Beds with pipeclay; *j*, London Clay; *k*, Woolwich and Reading Beds; *l*, Chalk.

another pit on the north side of the limestone, and after reaching a depth of about 7 feet I found what I had been looking for, namely, beds of limestone which I would refer to a lower horizon in the Bembridge Series. These yielded good results, as I obtained from them *Bulimus* (two species), *Cyclotus* (two species), *Helix* (two species), *Clausilia* (two species), *Achatina costellata*, and the so-called eggs of *Bulimus*: altogether about twenty species, some of which have not yet been determined. The marls in the old excavations, still to be seen some way down the hill-side, which were explained by Mr. Hudleston as due to the crumbling away or waste of the limestone from the top of the hill, I believe are part of the Lower Headon Series, from which marl was formerly dug for manuring the land. A good dressing of this was supposed to last from seven to ten years. The marl of Creechbarrow is, however, much more sandy than any I have seen in the corresponding beds elsewhere. When I was a boy of seven or eight years of age I should say there could not have been less than fifty men employed at this work. I have many times watched them digging, and they occasionally turned up portions of the freshwater and mud tortoises *Trionyx* and *Emys*.

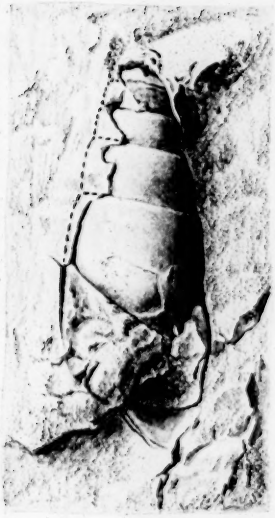
This marl has an extensive range and may some time be of use

again; it extends from Whitecliff Bay to Headon Hill, by Hordle, Lymington, Brockenhurst, and Lyndhurst, and various other places in the New Forest; it is then lost until we reach Creechbarrow Hill, where we find it again in the disused marl-pits referred to above. At Cut-walk Hill, where it was once extensively worked, a part of the Middle Headon Series is passed through before reaching the marl. At the base we frequently find specimens of the beautiful little *Voluta geminata* and other marine shells. Sir Charles Lyell when a young man of about 17, crossing a field with some sportsmen, picked up several of those fossils, and about twenty years afterwards sent specimens to F. E. Edwards, who was then preparing his Monograph on the Eocene and Oligocene Mollusca. I was at that time living at Milford, and Mr. Edwards wrote asking if I would try to find the locality. This I did, and made a good collection of fossils from Cut-walk Hill, one mile and a half north of Lyndhurst. The Rev. O. Fisher and the Rev. John Compton, Rector of Lyndhurst, visited the localities with me and collected a considerable number of fossils. Sir Charles Lyell, Professor Prestwich, and Sir W. H. Flower also visited the place for the purpose of studying the formations. The Rev. O. Fisher will, I am sure, corroborate my statements respecting the digging of the marl and the finding of the fossils at Brockenhurst, Lyndhurst, and elsewhere in that district.

This, I believe, is the first time that the Oligocene formation has been shown to occur in the Isle of Purbeck, and it will now be seen that it had a much more extensive range than had previously been supposed. Beginning at Whitecliff Bay it runs across the larger part of the parish of Bembridge, over the Solent to Hordle, Lymington, Beaulieu, Brockenhurst, and Lyndhurst, and extends thence to Creechbarrow Hill, about 7 miles west of Studland Bay. When engaged in making a collection for the Marchioness of Hastings, I found at Efford Hill a disused marl-pit quite rich in vertebrate remains, and I there collected portions of a crocodile's jaw with teeth, various mammalian remains, with *Emys* and *Trionyx*. These specimens are now preserved in the British Museum (Natural History), South Kensington. The marls which are found between the 400 and 500 foot contour-lines I regard as Lower Headon, and are the same as those which were formerly so extensively worked for manuring the land. It can now be seen that if we allow this to be Lower Headon we have space enough between it and the top of the hill for the Middle and Upper Headon, the Osborne, and the Bembridge Series. By taking the average level of the Pipeclay Series, say at the 337 foot contour, we shall leave 300 feet to the top of the hill, and allowing 50 feet as the thickness from the Pipeclay to the top of the Lower Bagshot Series, we shall have 250 feet for the Bracklesham, Barton, and the whole of the Oligocene; from which it will be seen that the hill may contain all the formations which occur in the corresponding position in the Isle of Wight.[1] The sand and flints described by Mr. Hudleston, and

[1] The only formations which have not been satisfactorily proved to occur are the Bracklesham, the Barton, and the Middle and Upper Headon. I have no doubt that those could be found in the hill by the sinking of pits and perhaps of a few boreholes.

1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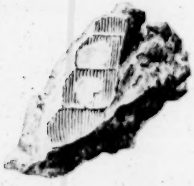
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*T. A. Brock del.*

Fossils from the Benbridge Limestone, Creechbarrow Hill.

considered by him to be of Lower Bagshot age, I regard as Pleistocene drift, such as may be met with in many places, not only in the Isle of Purbeck, but in the New Forest and the Isle of Wight. At the Rabbit Warren at Headon Hill there is nearly or quite 100 feet of sand and flint gravel, the flints being in every respect exactly similar to those from Creechbarrow. One of the workmen picked up, at a depth of about 13 feet, in one of the pits a piece of Bembridge Limestone associated with the flints in the gravel, which is quite conclusive evidence that the gravel cannot be of Bagshot age.

In conclusion, I should like to thank Mr. A. H. Bloomfield for valuable assistance, and to assure any persons visiting the Isle of Purbeck for the purpose of studying its stratigraphy or collecting fossils that they would do well to secure his services.

EXPLANATION OF PLATE XXXIV.

Fossils from the Bembridge Limestone of Creechbarrow Hill, Purbeck, in the Sedgwick Museum, Cambridge, collected by H. Keeping.

Figs. 1, 2. *Amphidromus* [*Bulimus*] *elliptica* (Sowb.). 1, with shell preserved; 2, internal cast.
,, 3. Egg of *Amphidromus* (?).
,, 4. *Cyclotus cinctus*, Edwards; × 1½.
,, 5. *Helix occlusa*, Edwards.
,, 6. *Glandina* [*Achatina*] *costellata* (Sowb.).
,, 7, 8. *Clausilia striatula*, Edwards. 7, natural external cast, × 1½. 8, wax impression of external cast, × 1½.

## III.—The Residual Earths of British Guiana commonly termed 'Laterite'.

By Professor J. B. Harrison, C.M.G., M.A., F.G.S., F.I.C., assisted by K. D. Reid, Assistant Analyst British Guiana.

On pages 20–2 and 99–105 of the *Geology of the Gold Fields of British Guiana* I gave a condensed account of the residual earths derived from the gradual decomposition of igneous rocks in situ which characterize wide areas in British Guiana as well as in the neighbouring countries of Venezuela, Dutch Guiana, French Guiana, and Brazilian Guiana. This deposit forms in many places a widespread very thick blanket-like coating to the igneous rocks from which it is derived, and owing in many places to its striking resemblance in general properties to the typical Indian formation described by Buchanan in 1807 it has been alluded to by many authors and by numerous mining engineers as 'laterite'. I gave on p. 101 two analyses of lateritic deposits which I selected from many I had made as showing the general composition of the earths. Unfortunately I omitted to show in them separately, as I had done in the original analyses, the proportions of silica present as quartz and of that present in a combined state. If I had done this it would have been seen that the earths contained but little combined silica and a relatively high proportion of alumina presumably present in the state of hydrate. For instance, in the Tumatumari sample which I collected myself from a deep cutting in the laterite lying on the diabase of the Tumatumari cataracts a few feet only above the surface of the unaltered rock, out of 51·76 per cent. of silica 49·35 is in the form of quartz, leaving 2·41 per cent. in the combined state in the presence of 24·55 per cent.

of alumina. I drew attention to this in a report on the soils of the interior of British Guiana published in 1902 in the following words: "A very large proportion of the alumina present is in the form of the hydrate, bauxite." As in the work on the Geology of the Gold Fields I was not dealing with the question of the presence of free alumina in the decomposition products of igneous rocks, but with the movements, the segregation, and the concentration into grains of the gold originally disseminated in certain of them, I contented myself by giving a reference to the full account and discussion of the Guiana laterites in Dr. G. C. Du Bois' monograph "Beitrag zur Kenntnis der Surinamischen Laterit", which was published in 1903 in *Tschermak's Mineralogische und Petrographische Mitteilungen*. A reference to this work would have shown that aluminous masses occur in the laterites of the Guianas and in Surinam, more especially in the re-arranged detrital deposits classed by Du Bois as "alluviale laterite". Unfortunately a reviewer of the work in the Imperial Institute Bulletin, vol. vii, No. 1, 1909, did not realize my object in thus referring to Du Bois' monograph, and therefore made unfavourable comments on my use of the term 'laterite', which term he stated "should be restricted to that product of weathering in hot moist climates which contains free aluminium hydroxide".

His comments have given rise to the recent correspondence between Mr. J. B. Scrivenor and Mr. T. Crook, in which the latter writes somewhat scathingly of "some people", amongst whom I am not ashamed to be included, who use the term laterite in the wide sense it is at present very largely employed by technical geologists, mining engineers, and tropical agriculturists. But in my opinion Mr. Crook is too severe in his strictures, strictures which appear to be based on a somewhat restricted view of the nature of the deposits in question, on the assumption that they mainly consist of masses of hydrated alumina—bauxite, gibbsite, or diaspore, or mixtures of them—which actually occur only in places in laterite; and I am quite unable to agree with him that the application of the term to such clays, iron-ores, etc., as I used it for is "wholly unwarranted", and that my use of the term is "unscientific" and one that "cannot properly be adopted by geologists". The British Guiana deposits are "a complex product . . . characterized by the presence of hydrated alumina, but usually containing also notable amounts of titanium and iron oxides, whilst free silica is generally present and hydrate of silicate of alumina is not necessarily absent", and the following account of these deposits formed by the decomposition of igneous rocks in situ and in some of which in parts hydrated alumina occurs may be of interest.

As far as my experience goes, the presence of free alumina in quantity in the residual earths resulting from the decomposition of igneous rocks in British Guiana characterizes rocks the felspars of which are mainly of the albite-anorthite series, whilst the residual deposits from rocks in which alkali-felspars such as orthoclase, anorthoclase, microcline, and albite are predominant, consist largely of kaolinite or of sericitic micas with kaolinite.

The general compositions of the soils found in aluminous lateritic areas are shown in the following analyses:—

TABLE I.—ANALYSES OF LATERITE SOILS.

| Locality. | Rock whence derived. | Loss on Ignition. | Gravel. | Quartz Sand. | Clay, Silica, and Insoluble Silicates. | Iron Peroxide. | Alumina. | Manganese Oxide. | Calcium Oxide. | Magnesium Oxide. | Potassium Oxide. | Sodium Oxide. | Phosphoric Anhydride. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mazaruni River—* | | | | | | | | | | | | | |
| Hiamaraka Creek . . . | Gabbro | 10·01 | nil | 18·40 | 36·86 | 11·23 | 22·56 | nil | ·22 | ·10 | ·01 | ·57 | ·04 |
| Hiamaraka Hill . . . | ,, | 6·43 | 57·00 | 9·89 | 4·83 | 10·57 | 10·60 | ·06 | ·06 | ·06 | ·01 | ·02 | trace |
| *Barima River—* | | | | | | | | | | | | | |
| Arakaka . . . . . | Diabase | 5·45 | 37·60 | 23·05 | 21·40 | 7·32 | 1·92 | ·06 | ·16 | ·16 | ·02 | ·03 | trace |
| *Potaro River—* | | | | | | | | | | | | | |
| Tumatumari . . . . | Diabase (dolerite) | 11·18 | nil | 49·35 | 3·08 | 11·34 | 24·55 | nil | ·23 | ·21 | ·21 | ·14 | trace |
| Potaro Landing . . . | ,, | 6·89 | 5·70 | 19·10 | 58·10 | 4·76 | 5·11 | ,, | ·05 | ·05 | ·05 | ·22 | ·07 |
| Konawaruk Road, 12 miles | ,, | 3·47 | 23·10 | 38·12 | 20·58 | 6·98 | 7·50 | ,, | ·02 | ·03 | ·06 | ·12 | trace |
| ,, 14 ,, | ,, | 6·92 | 6·30 | 24·87 | 42·21 | 8·90 | 10·54 | ,, | ·08 | ·05 | ·03 | ·08 | ·01 |
| ,, 14½ ,, | ,, | 8·12 | 38·30 | 21·95 | 6·39 | 11·83 | 12·92 | ,, | ·12 | ·07 | ·08 | ·16 | trace |
| ,, 16 ,, | ,, | 7·87 | 3·10 | 13·60 | 42·45 | 17·60 | 14·76 | ,, | ·09 | ·23 | ·04 | ·10 | ·16 |
| *Aruka River—* | | | | | | | | | | | | | |
| Maburima . . . . . | Hornblende-schist | 16·16 | 9·10 | ·35 | 29·16 | 15·65 | 35·92 | ,, | ·01 | ·07 | ·02 | ·91 | trace |
| Woopu . . . . . | ,, | 6·46 | 57·30 | 3·41 | 11·80 | 8·46 | 12·16 | ,, | ·01 | ·04 | ·01 | ·03 | trace |
| Issorora . . . . . | Epidiorite | 10·53 | 40·60 | 1·06 | 16·67 | 14·58 | 16·30 | ·06 | ·16 | ·08 | ·04 | ·06 | ·01 |
| *Barama River—* | | | | | | | | | | | | | |
| Hyama . . . . . | Hornblende-schist | 11·31 | 1·60 | 27·65 | 20·40 | 19·13 | 18·69 | ·72 | ·11 | ·15 | ·04 | ·11 | ·04 |
| 6 miles from Towakaima . | ,, | 4·80 | 20·30 | 38·53 | 22·97 | 3·16 | 9·83 | ·04 | ·09 | ·16 | ·03 | ·07 | trace |
| Takatu Creek . . . . | Chlorite schist | 9·30 | nil | 49·13 | 24·65 | 5·22 | 10·93 | ·32 | ·10 | ·12 | ·04 | ·10 | ·06 |
| *Demerara River—* | | | | | | | | | | | | | |
| Malali . . . . . | Diabase | 5·58 | 49·60 | 7·56 | 20·04 | 6·08 | 10·86 | nil | ·08 | ·07 | ·01 | ·10 | trace |
| Akyma . . . . . | Porphyrite | 8·32 | | 45·71 | 35·78 | 3·07 | 6·53 | ,, | ·12 | ·17 | ·18 | ·01 | trace |
| Christianburg . . . . | ,, | 5·39 | | 40·43 | 50·21 | 1·31 | 2·44 | ,, | ·11 | ·02 | ·08 | trace | ·01 |

The analyses of the soils were made in the manner usual in analysing them. The soils were digested in hydrochloric acid containing 20 per cent. of real acid at the temperature of boiling water for five working days, and the determinations of the constituents dissolved were made by well-known processes of analysis, a description of which it is not necessary to give here.

Although the analyses are of value as indicating the general characters of the soils on the residual earths in the lateritic areas and as showing in some cases the presence of alumina in a state or states in which it is readily dissolved by hot diluted hydrochloric acid in higher proportions than are usually dissolved from either temperate or tropical soils, it is evident that they do not indicate whether the alumina which is soluble in hydrochloric acid is present in the form of hydrate or as fairly easily decomposable silicates.

As I pointed out in a paper on the Oceanic Rocks of Barbados (Q.J.G.S., vol. xlviii, May, 1892, pp. 190, 191), the action of hydrochloric acid in the silicates present in earths and clays is dependent for its extent on variations in the strength and the temperature of the acid and in the duration of its action. This is true also of other acids. It is not feasible as far as my experience goes to regulate these factors so that only the uncombined or hydrated alumina present in an earth is dissolved without any of the aluminous silicates being attacked and supplying some of their alumina for solution in the acid. Hence it is necessary in the study of the earthy decomposition products of rocks with the view of ascertaining the nature and proportions of their proximate components to analyse them by methods which ensure their complete decomposition, and guided by the indications of microscopical examination of the earths to calculate the proportions of their proximate constituents by means of the figures obtained by the analyses.

Aided to a very great extent by Mr. K. D. Reid, an Assistant Analyst in the Department of Science and Agriculture of British Guiana, I have made in addition to earlier ones a series of more complete analyses by following with some additions and modifications the methods I described in papers dealing with the compositions of the oceanic rocks of Barbados and of certain oceanic oozes (Q.J.G.S., vol. xlviii, pp. 182–3, May, 1892; vol. li, p. 314 et seq., August, 1895).

In the discussions which follow in this paper the probable proximate composition of the samples which have been examined have been calculated on the assumption that the minerals present are in the condition of maximum hydration corresponding to the proportions of water found in the samples, that the potassium, sodium, and calcium oxides[1] found therein are in the form of felspars or of sericite, according to the indications of microscopical and physical examinations; the magnesium oxide has been calculated to talc, its most stable form of hydrated silicate under weathering; the portion of the combined silica not required in these combinations has been calculated to

[1] Calcium oxide is usually found in very small proportions, and in the residual earths is generally present as a constituent of epidote.

kaolinite,[1] whilst the residuary alumina unallotted to them has been assumed to be present as aluminium hydrate, the composition of the hydrate being dependent on the relative available proportions of alumina and of water; and the hydrate so calculated for convenience has been termed bauxite—a possible terminological inexactitude which I trust will be condoned by Mr. Crook.

In samples which showed the presence of an excess of water, after allowing for the various hydrated aluminous and magnesian minerals assumed to be present, the excess of water has been calculated as combined with iron peroxide to form limonite. I have not attempted in cases where the excess of water is insufficient to combine with all the iron oxide, other than that present as ilmenite, to form limonite, to show the iron oxide as one of the ill-defined reputed hydrates of iron, but have regarded it as being in the form of mixtures in various proportions of hæmatite and limonite. The titanium oxide has been shown as present in the form of ilmenite, a mineral very resistant to decomposition under the conditions existent in the Guianas, and constantly found in the residual earths and the ferruginous and aluminous concretionary masses.

### The Residual Products of the Weathering of Rocks of the Diabase-Gabbro type.

To ascertain the nature of the residua resulting from the decomposition in situ under tropical conditions of basic igneous rocks, a study has been made of the various components of such decomposition-products at the Agricultural Experiment Station of this Department at Issorora Hill, part of the Aruka range, which is situated about 17 miles from the seashore, in the north-western district of British Guiana, about 130 miles to the north-west of Georgetown, and about 10 miles from the Venezuelan boundary, the Amacura River. This isolated range of low hills, which extends for about 20 miles in a south-westerly direction, consists of epidiorite and of hornblende-schist, the metamorphosed products of a diabase or gabbro, which are covered by a blanket-like coating of red earth with, in its upper layers, numerous blocks of concretionary ironstone, and this covering supplies an excellent example of the material not unfrequently described as laterite by agriculturists, engineers, and mining experts.

Examination in the field shows that the covering consists of a gravelly bright-red earth, similar to that which is termed in Brazil *terra roxa* and in Venezuela *cascajo*, in which is embedded masses of concretionary ironstone, varying greatly in size, in colour, and in texture, but usually being ruddy, scoriaceous, cindery, or slaggy-looking masses, with innumerable small cavities; large angular masses of white quartz, and numerous small pisolitic granules of ironstone. Concretionary ironstone of the kind above described is known in

[1] The statement that kaolinite is never a product of weathering but is always due to deep-seated changes cannot be accepted for the Guianas, where granitic and similar rocks are found converted by surface changes (weathering) into quartziferous kaolins, and the various stages of such conversion can be readily followed in the field in many places.

Surinam as *Kakerlogston*, in French Guiana as *Roche à Ravet*, and is termed in Brazil *Pedra de ferro* and in Venezuela *Moco de hierro*. Samples of the various types of ironstone, of the quartz and of the earth with its ferruginous pisolites, which are present in it to the extent of 45·8 per cent. of its weight, were collected at my direction by the officer in charge of the station, and have been examined by Mr. Reid and myself in the Government Laboratory of British Guiana.

The ultimate composition of the epidiorite at Issorora, of the red earth, of the pisolitic ironstone granules, and of the various types of the concretionary ironstone found there was determined with the results shown in Table III (p. 445).

Aided by microscopical examinations of the material the mineralogical components of the rock and of its decomposition-products have been calculated as shown in the following table:—

Table II.

| | Epidiorite. | Red Lateritic Earth. Nos. 1 and 2. | Ironstone Pisolites. | Concretionary Ironstones. | | |
|---|---|---|---|---|---|---|
| | | | | Nos. 1 and 2. | Nos. 3 and 4. | Nos. 5 and 6. |
| Quartz | 1·3 | 2·5 | 1·4 | ·1 | ·1 | ·1 |
| Colloid Silica | | | | | | |
| Orthoclase | ·5 | ·8 | 1·5 | | | |
| Plagioclase | 55·1 | 2·9 | ·4 | 1·3 | ·6 | ·8 |
| Hornblende and Pyroxene | 38·0 | nil | | | | |
| Magnetite | 2·8 | | | | | |
| Hæmatite | | 23·7 | 55·4 | 18·2 | 29·0 | 19·0 |
| Limonite | | | 15·9 | 74·1 | 54·0 | 12·5 |
| Ilmenite | 1·7 | 4·3 | 3·6 | ·6 | ·6 | ·6 |
| Kaolinite | | 39·4 | 3·7 | 2·4 | 7·7 | 24·5 |
| Talc | | 2·3 | ·7 | 1·4 | 1·7 | ·8 |
| *Bauxite | | 24·2 | 17·1 | 1·6 | 6·6 | 41·7 |
| *Minor constituents | ·6 | | ·3 | ·3 | | |
| | 100·0 | 100·1 | 100·0 | 100·0 | 100·3 | 100·0 |
| *Diaspore | | 12·0 | | | | 6·6 |
| Gibbsite | | 12·2 | 17·1 | 1·6 | 6·6 | 35·1 |
| *Total Alumina present in Bauxite | | 18·9 | 11·2 | 1·0 | 3·8 | 28·6 |

The foregoing representatives of the class of more or less ferruginous and aluminous deposits which in the Guianas for many years commonly have been termed 'laterite' do not possess, except in the case of the concretionary ironstones, the property laid down by Buchanan as being characteristic of 'laterite'—that of 'setting' or hardening on exposure to the atmosphere. Parts of them agree to some extent with what has been laid down as the modern scientific qualification

TABLE III.—ISSORORA HILL, ARUKA, NORTH-WESTERN DISTRICT.

| | Epidiorite. | Red Lateritic Earth. | | Pisolitic Ironstone in Nos. 1 and 2 45% | Concretionary Ironstones. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No. 1. | No. 2. | | Dark brown with yellow patches. No. 1. | Light brown with yellow patches. No. 2. | Light brown, light yellow patches. No. 3. | Brownish yellow with red spots. No. 4. | Dark yellow veined with brick-red. No. 5. | Dark brown with yellow patches and with white streaks. No. 6. |
| Quartz | 1·30 | 1·59 | 3·48 | 1·38 | ·10 | ·09 | ·08 | ·08 | ·23 | ·06 |
| Colloid Silica | — | ·10 | ·10 | ·18 | ·16 | ·14 | ·18 | ·63 | ·03 | ·38 |
| Combined Silica | 47·76 | 25·13 | 22·69 | 3·37 | 2·55 | 2·69 | 4·27 | 5·58 | 9·56 | 14·25 |
| Aluminium Oxide | 18·87 | 31·83 | 33·37 | 13·03 | 2·47 | 2·55 | 6·69 | 7·09 | 37·10 | 39·83 |
| Iron Peroxide | 1·89 | 25·60 | 26·73 | 71·86 | 82·15 | 81·59 | 71·55 | 76·33 | 38·39 | 21·53 |
| Iron Protoxide | 4·51 | — | — | — | — | — | — | — | — | — |
| Magnesium Oxide | 10·95 | ·96 | ·60 | ·14 | ·66 | ·25 | ·81 | ·25 | ·25 | ·22 |
| Calcium Oxide | 11·70 | ·81 | ·07 | ·07 | ·17 | ·35 | ·17 | ·08 | ·22 | ·09 |
| Sodium Oxide | 0·97 | ·11 | ·04 | nil | traces | traces | traces | trace | trace | trace |
| Potassium Oxide | 0·06 | ·07 | ·25 | ·28 | traces | traces | traces | trace | trace | trace |
| Water | 0·43 | 12·52 | 10·83 | 8·28 | 11·76 | 11·50 | 12·45 | 10·01 | 14·10 | 22·64 |
| Titanium Oxide | 0·88 | 1·70 | 2·35 | 1·87 | ·31 | ·23 | ·19 | ·27 | ·49 | ·17 |
| Phosphoric anhydride | trace | trace | trace | nil | nil | trace | trace | trace | trace | trace |
| Manganese Oxide | 0·34 | ·10 | nil | nil | nil | nil | ·15 | nil | nil | 1·08 |
| | 99·66 | 100·52 | 100·42 | 100·16 | 100·33 | 99·39 | 99·54 | 99·72 | 100·37 | 100·25 |

for a rock to be termed 'laterite'—the fact that they are "essentially characterized by the presence of free hydrate of alumina"; but the question remains: If it is allowable to term 'laterite' the earth and its pisolites which contain, in round figures, 24 per cent. of 'bauxite', and the concretionary masses which contain 42 per cent. of it, what are their accompanying masses which contain only from 2 to 7 per cent. of bauxite to be called? Are we to find another name for these masses whilst they are in situ, or may we not reasonably include them with the other components of the residuary products of the rocks as a whole under a wide-meaning term 'laterite'?

Another type of the deposits formed by the decomposition of diabase and of hornblende-schist in situ is illustrated by samples from Tumatumari, Potaro River; the Penal Settlement at Mazaruni, Mazaruni River; and the Omai Falls at the Omai Gold Mine, Essequibo River. Their compositions and those of the rocks from which they are derived are as follows:—

Table IV.

| | Tumatumari. | | Omai Falls. | | Mazaruni. | |
|---|---|---|---|---|---|---|
| | Diabase. | Laterite. | Diabase. | Laterite. | Hornblende Schist. | Laterite. |
| Quartz | 3·20 | 47·35 | 6·50 | 38·66 | 7·60 | 32·51 |
| Colloid Silica | | ·06 | | ·17 | | ·05 |
| Combined Silica | 47·99 | 3·30 | 46·75 | 7·90 | 44·10 | 14·93 |
| Aluminium Oxide | 15·80 | 26·33 | 17·16 | 18·41 | 15·94 | 34·14 |
| Iron Peroxide | 3·08 | 10·67 | 4·27 | 22·35 | 3·84 | 7·64 |
| Iron Protoxide | 11·20 | [illegible] | 8·26 | | 10·56 | |
| Magnesium Oxide | 5·63 | ·21 | 6·10 | ·12 | 5·54 | ·11 |
| Calcium Oxide | 9·58 | ·23 | 7·46 | ·11 | 9·60 | ·01 |
| Sodium Oxide | 2·09 | ·14 | 2·50 | ·15 | 1·87 | ·53 |
| Potassium Oxide | 0·60 | ·21 | 0·69 | ·47 | ·08 | ·48 |
| Water | 0·30 | 11·28 | 0·32 | 10·97 | ·30 | 9·00 |
| Titanium Oxide | 0·40 | ·67 | 0·32 | ·50 | ·30 | ·90 |
| Phosphoric Anhydride | 0·008 | trace | trace | trace | ·01 | ·02 |
| Manganese Oxide | trace | nil | 0·12 | nil | trace | nil |
| | 99·878 | ~~108·71~~ 100·45 | 100·45 | 99·81 | 99·74 | 100·32 |

Corrected in Dec. issue P562.

The mineralogical components of the rocks and of their resultant laterites have been calculated as shown in Table V (p. 447).

These residual earths are as characteristic of many of the residuary products of basic rocks as those at Issorora are of others. But in them, in place of the silica segregating out into masses of quartz, and only occurring to a very limited extent as fine gravel or sand, the quartz occurs in quantity as very fine angular gravel and sharply angular sand of very varying degrees of division, but mostly of exceeding fineness, dispersed through the mass, by far the greater part of the quartz being of secondary origin. In them, as a rule, the

concretionary ironstones are less in evidence than they are at Issorora, but in time the weathered surfaces of the earths become covered by quartz-sand and gravel, with in places pisolitic granules of concretionary ironstone, whilst they contain here and there in their upper parts masses of concretionary ironstone, some of which attain weights of over a ton, and which masses, as are some of those at Issorora, are in parts more or less bauxitic.

TABLE V.

| | Tumatumari. | | Omai Falls. | | Mazaruni. | |
|---|---|---|---|---|---|---|
| | Diabase. | Laterite. | Diabase. | Laterite. | Hornblende Schist. | Laterite. |
| Quartz | 3·2 | 47·3 | 6·5 | 38·7 | 7·6 | 32·5 |
| Colloid Silica | | ·1 | | ·2 | | |
| Orthoclase | 3·3 | 1·3 | 3·9 | 2·8 | ·5 | 2·8 |
| Plagioclase | 49·8 | 2·3 | 40·6 | 1·8 | 30·9 | 4·5 |
| Hornblende and Pyroxene | 38·0 | | 42·2 | | 53·9 | |
| Magnetite | 4·4 | | 6·3 | | 5·6 | |
| Hæmatite | | 10·0 | | 7·2 | | 6·7 |
| Limonite | | | | 17·2 | | |
| Ilmenite | 0·8 | 1·3 | 0·6 | ·9 | 0·6 | 1·7 |
| Kaolinite | | 1·3 | | 10·1 | | 20·1 |
| Talc | | ·7 | | ·4 | | ·3 |
| *Bauxite | | 36·0 | | 20·5 | | 31·5 |
| *Minor constituents | 0·5 | | | ·2 | 0·9 | |
| | 100·0 | 100·3 | 100·1 | 100·0 | 100·0 | 100·1 |
| *Diaspore | | 5·2 | | | | 24·0 |
| Gibbsite | | 30·8 | | 20·5 | | 7·5 |
| *Total Alumina present in Bauxite | | 25·0 | | 13·4 | | 25·3 |

As a rule they do not show the hardening properties of Buchanan's laterite, but if we are to take the presence of free alumina in the form of hydrate as the definitive test of whether a mass has a right to be termed 'lateritic', they are clearly lateritic earths.

*The Residual Earths from Sericite and Chlorite Schists.*—As examples of a type of residuary earths which exhibit to a considerable extent the setting properties from which Buchanan derived the term laterite, may be adduced certain ferruginous earths which contain sericitic micas in such quantities that the principal aluminous components are sericite, kaolinite, and bauxite, instead of being kaolinite and bauxite, with a little residuary felspar, as are those of the types already considered. The best examples of these I have seen occur at the Omai Gold Mines, Essequibo River, where a ditch between two and three miles in length and several tunnels were

cut through them for the purpose of conveying water for the hydraulic workings. Their mass was quite soft when first dug into, but gradually became indurated on exposure to the atmosphere to the consistency of soft rock, so that the sides of the ditch and the sides and roofs of the tunnels became firm enough to allow of the rapid passage of water along and through them without any artificial supports being required either for the sides of the trench or the roofs of the tunnels.

The hardening was accompanied by a gradual darkening in the colour of the rock, this indicating changes in the states of hydration of the oxides of iron present in them.

At Omai these earths are largely the residua from the decomposition of sericitic and of chloritic schists, which latter frequently contain sericite in considerable proportions.

At Omai the rocks are completely decomposed to depths of 100 to 150 feet, and owing to this and to the intricate nature of the complex of sericitic, hornblendic, and chloritic schists, epidiorites and porphyroids, traversed by veins of sericitized aplite and felspar-porphyrite and by sills of diabase, it is not possible to ascertain which rock or rocks by decomposition gave rise to the sericitic earths. Hence I have not analysed the specimens of sericitic and other schists of which the cores of the diamond-drill borings obtained at Omai largely consist, and therefore it is not feasible to contrast the compositions of the residual earths with those of the rocks from which they have been derived.

The ultimate compositions of representative samples of the sericitic earths are as follows:—

Table VI.

| | Brownish red. | Yellowish brown. | Yellowish brown. | Purplish red. |
|---|---|---|---|---|
| Quartz . . . . . | 11·17 | 31·44 | 37·28 | 7·05 |
| Colloid Silica . . . | ·30 | ·14 | ·23 | ·08 |
| Combined Silica . . | 24·04 | 19·58 | 16·54 | 14·53 |
| Aluminium Oxide . . | 23·94 | 27·21 | 24·98 | 21·34 |
| Iron Peroxide . . . | 24·65 | 8·78 | 7·57 | 39·03 |
| Magnesium Oxide . . | ·30 | ·23 | ·21 | ·08 |
| Calcium Oxide . . . | ·10 | ·06 | ·06 | ·05 |
| Sodium Oxide . . . | ·10 | trace | trace | ·25 |
| Potassium Oxide . . | 1·27 | 1·55 | 1·85 | 2·58 |
| Water . . . . . | 11·70 | 9·79 | 11·27 | 13·22 |
| Titanium Oxide . . | 2·31 | ·65 | ·70 | 2·35 |
| Phosphoric Anhydride | trace | trace | nil | nil |
| Manganese Oxide . . | nil | nil | nil | trace |
| | 99·88 | 99·43 | 100·69 | 100·56 |

The average proximate mineralogical composition of the earths when calculated out in the manner already described is as follows:—

TABLE VII.

| | |
|---|---|
| Quartz | 21·7 |
| Colloid Silica | ·2 |
| Sericite | 16·9 |
| Hæmatite | 2·6 |
| Limonite | 18·6 |
| Ilmenite | 2·9 |
| Kaolinite | 23·0 |
| Talc | ·7 |
| *†Bauxite | 13·5 |
| | 100·1 |
| *Gibbsite | 13·5 |
| †Total Alumina present in the form of Bauxite | 8·9 |

The surfaces of the residual earths are covered with ironstone, gravel, and conglomerates, whilst at depths of some feet from the surface layers of angular quartz gravel occur. In many places the earths are seen to be traversed by numerous thin veins of quartz, some of which are normal to the original schists, whilst others are clearly of secondary origin, their silica having been derived from the decomposition of the felspar and ferruginous minerals of the rocks.

Layers of ironstone conglomerates and masses of concretionary ironstone similar to those at Issorora everywhere cover to a depth of about $2\frac{1}{2}$ feet the surface of the hills at Omai. Like those at Issorora the concretionary ironstones are in places more or less aluminous.

*Laterite from Felsite or Porphyrite, Demerara River.*—At Christianburg, on the Demerara River, about 58 miles south of Georgetown, where the Government has a Para rubber experiment station, the surface of the low hills is a sandy soil which rests on beds of cream-coloured, reddish-grey, or red highly aluminous laterite or 'bauxite'. The bauxite is also exposed in shallows in the bed of the river between Christianburg and Wismar, and it gives rise to a low hill at Akyma, some 11 miles south of Christianburg. Microscopic examinations of the bauxite show that it has been derived from a felsite, a porphyrite, or possibly a tuff. Felsite and porphyrite are exposed in the Kumaru Creek close to Akyma Hill, where they are intrusive in gneiss. At Christianburg the bauxite apparently is underlain by a pale buff-coloured arenaceous clay.

In this district generally as well as at the Christianburg and the Akyma Hills the surface soil over the lateritic decomposition-products is a sand varying from white, glistening, almost pure quartz sand, containing over 96 per cent. of quartz, to a brownish highly arenaceous soil, with from 40 to 50 per cent. of quartz, the former variety containing less than $\frac{1}{2}$ per cent., the latter from 2 to 6 per cent. of free alumina, whilst below it the subsoil contains less quartz—from 20 to 45 per cent.—and somewhat higher proportions of free alumina, these ranging from 5 to about 7 per cent.

The soil is underlain by a somewhat thick deposit, the depth of which has not been determined, of masses of cream-coloured bauxite, which in parts are more or less stained with iron, or where reddish grey to red in colour are more or less ochreous or limonitic. Some

masses resemble in colour and general characters the concretionary ironstones described under numbers 5 and 6 of the Issorora District. Specimens of this kind were obtained from a shoal in the Demerara River near Wismar, about half a mile south of Christianburg.

The compositions of the samples of the sands, of the bauxites, of the underlying clay, and of the hornblende-felspar-porphyrite from which they were presumably derived are as follows:—

TABLE VIII.

| | Hornblende Felspar Porphyrite. | Christianburg. | | | Bauxite or Laterite. | |
|---|---|---|---|---|---|---|
| | | Sand. | Bauxite or Laterite. | Clay. | Akyma. | Wismar. |
| Quartz | 34·10 | 96·80 | ·42 | 38·79 | ·67 | 4·71 |
| Colloid Silica | | | ·14 | ·53 | ·12 | ·62 |
| Combined Silica | 36·86 | 1·13 | 2·29 | 25·50 | 1·92 | 3·58 |
| Aluminium Oxide | 16·64 | ·97 | 67·28 | 21·16 | 64·86 | 45·14 |
| Iron Peroxide | 0·22 | ·64 | 1·53 | 3·74 | ·85 | 23·03 |
| Iron Protoxide | 1·48 | | | | | |
| Magnesium Oxide | 1·29 | ·02 | ·07 | ·49 | ·31 | ·31 |
| Calcium Oxide | 3·46 | ·08 | ·02 | ·08 | ·03 | trace |
| Sodium Oxide | 4·39 | ·08 | nil | ·48 | nil | nil |
| Potassium Oxide | 0·24 | ·01 | ·08 | 2·00 | ·15 | ·15 |
| Water | 0·68 | ·25 | 27·46 | 6·67 | 30·47 | 21·68 |
| Carbonic Anhydride | 0·42 | | trace | | trace | nil |
| Titanium Oxide | 0·38 | trace | 1·07 | ·67 | ·75 | 1·12 |
| Phosphoric Anhydride | 0·006 | ·006 | trace | trace | trace | trace |
| Manganese Oxide | 0·10 | trace | | nil | nil | nil |
| | 100·266 | 99·986 | 100·36 | 100·11 | 100·13 | 100·37 |

The proximate mineralogical compositions of the porphyrite, the bauxitic masses, and of the clay underlying the latter are as shown in Table IX (p. 451).

The bauxitic masses fully correspond to the typical laterites in the restricted sense laid down for the late Dr. Buchanan by Mr. Crook. They are when first dug fairly soft, and easily trimmed into shape for building purposes by a trowel or heavy knife. They have been used for building purposes in the foundations and retaining walls of the Government Saw Mill at Christianburg, and also in walls at Akyma. After exposure to the atmosphere the masses have quickly set and attained a hardness corresponding in the lighter-coloured or more purely bauxitic parts to somewhat less than three in Mohs' scale of hardness, and in the ferruginous parts to somewhat over that degree. The marked hardening is to a considerable extent confined to the exposed surfaces.

I have examined microscopically thin sections of the bauxite masses from Christianburg. Their general structure is that of a metamorphosed

felspar-porphyrite or tuff in which the original minerals with the exception of the ilmenite have been impregnated with or replaced by hydrates of alumina in an amorphous concretionary form. The amorphous matter is mingled here and there with very minute particles of quartz, and it is traversed by very thin veins of chalcedonic silica, some of which appears to be tridymite. The ilmenite is present in the form of widely, though sparsely, scattered exceedingly minute

Table IX.

| | Hornblende Fel-spar Porphyrite. | Christianburg. | | | Bauxite or Laterite. | |
|---|---|---|---|---|---|---|
| | | Sand. | Bauxite or Laterite. | Clay. | Akyma. | Wismar. |
| Quartz | 34·4 | 96·8 | ·4 | 38·8 | ·7 | 4·7 |
| Colloid Silica | | | ·1 | ·5 | ·1 | ·6 |
| Orthoclase | 1·4 | trace[1] | ·5 | 11·8 | ·9 | ·9 |
| Plagioclase | 51·0 | 1·1 | ·1 | 4·4 | | |
| Hornblende and Pyroxene | 12·0 | | | | | |
| Magnetite | | | | | | |
| Hæmatite | | ·6 | ·5 | 3·1 | ·1 | 21·9 |
| Ilmenite | ·8 | | 2·1 | 1·3 | 1·4 | 2·1 |
| Kaolinite | | 1·1 | 3·3 | 29·8 | 1·5 | 4·3 |
| Talc | | | ·2 | 1·6 | 1·0 | 1·0 |
| Calcite | ·9 | | trace | | trace | |
| Bauxite | | ·4 | 92·6 | 8·9 | 94·4 | 64·6 |
| Minor constituents | | | ·2 | | | |
| | 100·2 | 100·0 | 100·0 | 100·2 | 100·1 | 100·1 |
| Diaspore | | | 26·1 | | | |
| Gibbsite | | ·4 | 66·5 | 2·0 | 12·1 | 6·6 |
| Total Alumina present in Bauxite | | ·3 | 65·7 | 6·9 | 82·3 | 58·0 |
| | | | | 5·3 | 64·1 | 43·0 |

[1] Muscovite.

grains, none of it, however, being in the siliceous veins. The thin sections examined were cut from some of the more siliceous parts of the bauxite. The microscopical structure of the bauxite closely resembles that of the "Oolithartige Bauxit" of Surinam, described by Du Bois as follows on pp. 35–9 of his monograph "Beitrag zur Kenntnis der Surinamischen Laterit" (*Tschermak's Mineralogische und Petrographische Mitteilungen*, Band xxii, Heft i, 1903):—

"Only in a very thin section of the fresh, oolite-like substance could the separation of secondary silica be demonstrated with certainty. The ground-mass of the nodules and the cement is composed of feebly translucent yellow substance apparently amorphous. Some of the concentric parts—generally the outermost—are strongly impregnated with microscopic granules of chalcedony. The intermediate mass or

the cementing substance of the nodules is remarkably rich in secondary silicic secretions. Septarian-like veins which traverse obliquely the nodules also show the partial silicification."

The earth underlying the bauxite at Christianburg was microscopically examined, and was found to contain a considerable proportion of orthoclase felspar in a very finely divided angular condition. Some minute angular grains showing the striæ of plagioclase were also detected. It seems probable from this and from its chemical composition that the arenaceous clay was derived from a different rock to that which gave rise to the bauxite, possibly from the granitite-gneiss which is the principal component of the fundamental complex of the Demerara–Essequibo district.

(*To be continued.*)

## IV.—On the Superficial Deposits at the Foot of the Cheviot Hills between Wooler and Glanton.

By R. G. A. Bullerwell, M.Sc.

(PLATE XXXV.)

Introduction.—Lying at the foot of the Cheviot Hills are deposits of sand and gravel, which, between Wooler on the north and Glanton on the south, cover a considerable area, occupying the greater part of the lower valleys of the Breamish and other tributary streams of the Till. They form mounds and ridges running in different directions, often dividing and reuniting in a very irregular manner. They are indicated, along with deposits at greater altitudes, on the Drift Edition of the Map of the Geological Survey of England (Sheets 109 N.W. and 110 S.W.) as "sands and gravels of Glacial age". It is for the purpose of describing these accumulations and in some measure elucidating their source and mode of deposition that this paper is written.

Literature.—Concerning these sands and gravels very little has previously been published. Professor G. A. Lebour, M.A., M.Sc., F.G.S.,[1] doubtfully places them along with other deposits in Northumberland and Durham, evidently more recent than the Boulder-clay, under the head of "Upper Drift Sands and Gravels".

Writing in 1872 on "Langleyford Vale and the Cheviots", Dr. J. Hardy[2] noted the water-worn character of the gravels. "The Wooler Water," he says, "works its uncertain way among congeries of ancient gravels and rolled masses, often disturbing and ploughing them up, but adding nothing to the spoils brought thither by earlier and more intensified agencies that scooped the channel for the present diminished stream."

Earlier still, in 1865, Mr. Tate, F.G.S.,[3] in his paper "Records of Glaciated Rocks in the Eastern Borders", pointed out the well-rounded gravels which had previously been referred to as Glacial Moraines by Dr. Buckland.

[1] *Handbook of the Geology of Northumberland and Durham.*
[2] Proceedings of Berwickshire Naturalists' Club, 1872.
[3] Ibid., 1865.

Valuable information as to the condition of the Cheviots during the Glacial Period is to be obtained from Mr. C. T. Clough's memoir[1] "On the Geology of the Cheviot Hills", and from the paper by Professor P. F. Kendall, F.G.S., and Mr. H. B. Maufe, B.A., F.G.S.,[2] "On the Evidence of Glacier-dammed Lakes in the Cheviot Hills."

The Glacial deposits of the adjacent country between Wooler and Coldstream are described in the memoir by Mr. W. Gunn, F.G.S., and Mr. C. T. Clough, M.A., F.G.S.[3]

Physical Structure of the District.—The range of the Cheviots culminates in the north-east in the granite hills of Cheviot, Hedgehope, etc. This granite area is surrounded by tuffs and porphyrites contemporaneous with the Old Red Sandstone. Between Wooler and the Breamish the porphyrites present a steep but curved slope facing E.N.E. and east, and enclose between South Middleton and Roddam red marls, sands, and thick beds of conglomerate.[4] The range is intersected by several valleys, the present pigmy streams in many cases being grotesquely out of proportion to the amount of denudation, and presenting a striking contrast to the more powerful subaerial agents of denudation originally employed in their excavation.

Resting unconformably upon these rocks are those of the Carboniferous Series, consisting chiefly of sandstones, grits, and impure limestones. They extend outward from the Cheviot area, with a generally gentle slope towards the east. The Fell Sandstones of this series form ridges and crags at considerable elevation on the eastern side of the Till, their rugged and steep escarpments boldly contrasting with the rounded form of the porphyrites rising above the valley on the opposite side. All the streams included in the area are tributary to the Till, itself tributary to the Tweed, and which in its upper course is known as the Breamish, taking its rise in Cheviot, flowing first south-east, then east, and near Hedgeley sweeping round in a northerly direction.

Glaciation of the Cheviots.—While the higher summits appear never to have been overridden by foreign ice, but to have acted as independent centres of glaciation, two foreign streams advanced upon the Cheviots, one from the south-west and the other from the north, but whether they were contemporaneous or successive is not readily determined. Both the eastern and southern margins have evidently been overridden by foreign ice up to a height of 1000 feet, as indicated by striæ and the presence of transported boulders.

Mr. Clough has described the foreign rocks occurring in the drift near Skirlnaked and pointed out a track of foreign boulders crossing the porphyrite hills from the north to this locality. On the other hand, however, the striæ and boulders occurring on the south-east margin of the Cheviots indicate transport from the south-west.

On Carboniferous rocks west of Black Hill, Ford Moss, Messrs. Gunn and Clough found striæ indicating a direction from east to west.

[1] Memoirs of the Geological Survey of England and Wales.
[2] Transactions of Edinburgh Geological Society, vol. viii, 1902.
[3] Memoirs of the Geological Survey of the United Kingdom.
[4] [Basement Beds of the Carboniferous.—Ed.]

The northerly flow along the Cheviots was evidently produced by a deflection of this easterly or north-easterly flow from the Tweed Valley. On the sandstone of Bewick Hill are striations pointing direct north and south.

Description of Sands and Gravels.—Sands and gravels cover the tract between the high land above Wooler and Glanton Pike, and are bounded on the west by the Old Red Sandstone conglomerates or Basement Beds of the Carboniferous Series. The eastern limit is more difficult to define, but gravel and sand deposits abut against the Carboniferous rocks of Bewick Hill, and may extend into the Eglingham Valley. They form hummocks and meandering ridges continually dividing and reuniting in a most confusing and irregular manner, but with the long axes of the ridges most frequently running north and south. In the lower valley of the Breamish the sands and gravels are more diffused, but this may be due to subsequent re-arrangement by later agencies. The mounds and ridges may be well seen between Wooperton Station and New Bewick where the road crosses them, also between East Lilburn and the same station where the view looking towards Bewick Hill embraces a large tract covered with kame-formed ridges of gravel. The undulating formation is most pronounced in the areas adjacent to the river valleys where the deposits are thickest. In several cases the sands are cut through by streams and present steep sloping faces fronting the valleys. Such banks may be seen in Coldgate Water, Roddam Dean, near East Lilburn, and below Hedgeley Low Farm (Fig. 1, Pl. XXXV). The sand is composed of coarse irregular grains, and contains occasional well-rounded pebbles. The deposits generally follow the 300 feet contour-line.

The section below Hedgeley is almost entirely of sand, but contains limestone and porphyritic pebbles. It rises about 40 feet above the level of the alluvial plain. The banks may be followed for about a quarter of a mile and end in a spit which slopes gently eastward. The surface is a plateau, broken here and there into hummocks and hollows.

Many of the hummocks might be described as kame-formed and reach the contours of 300 and 400 and in a few cases to the 500 feet line. This is the greatest elevation to which it is necessary to refer for the purposes of the present paper. Whenever the 300 feet contour is the limit and any opportunity whatever given for examining the contained pebbles these are seen to be well rounded.

Generally speaking, coarse gravels are to be seen on the western boundary where the deposits abut against the Cheviots, passing into finer gravel, followed by sand, with sparsely occurring pebbles as they are traced eastward. The gravel is usually composed of material derived from rocks in the immediate neighbourhood (porphyrite, etc.), but a considerable quantity of it is evidently derived from foreign sources.

Much of the district covered with gravel is tilled, only a small area, apart from the low marshy soil of Hedgeley, etc., being devoted to pasturage. Where cultivated the soil is invariably heavily charged with pebbles of varying texture, and in early spring after heavy rains the hummocks resemble nothing so much as mere mounds of loose

well-rounded stones. Notwithstanding the thin gravelly soil, however, the farmers informed me that good crops are the rule.

Sections.—On the left bank of Wooler Water and following the 300 feet contour-line, sands and gravels are exposed and may be examined between Earle Mill and Coldgate Mill. A few yards south of the former the section consists of gravel, sand, and clay, irregularly bedded. The gravel is water-worn and rounded. False bedding which probably represents a rapid deposition of sand is shown by a banded appearance due to alternate layers of material of darker and lighter colour. Gravel and sand alternate irregularly with each other, and may be seen when the bedding is not obliterated by the falling down of the sand and clay from the upper portion of the section. South of this the entire section is sand with few pebbles. The bedding is very distinct.

At a point almost opposite Haugh Head and a few yards below the bridge a section showing coarse and fine gravel with sand is exposed. The bedding is clear, but layers of the same texture rarely extend for any great distance or continue across the entire length of the section, which is about 80 feet. The included rocks, which are without exception well rounded and water-worn, are of yellow sandstone, Carboniferous Limestone, and porphyrite, the largest being of arenaceous rock and measuring up to 15 feet in girth, together with smaller fragments of quartz, jasper, lydian stone, slate, and Silurian greywacke. Some of the gravel is cemented together, the cementing material being calcium carbonate. The coarse gravel frequently contains washings of fine gravel and sand. The section, which rises to about 30 feet above the river-level (see Fig. 2, Pl. XXXV), consists of the following:—

(*a*) 2½ feet, sand.
(*b*) 2½ feet, fine gravel and sand.
(*c*) 5 feet, coarse gravel.
(*d*) 2½ feet, fine gravel with a few large boulders.
(*e*) 5 feet, coarse gravel, continuous with (*g*).
(*f*) 2½ feet, fine gravel, bedded.
(*g*) About 10 feet, coarse gravel, with bed of fine gravel and sand about 2 feet from base. There is much limestone and yellow sandstone and several bands of sand and dirty gravel cemented together. Some of the cementing matter is oxide of iron, which gives a rusty appearance to the lower portion.

From this point up to Coldgate Mill are banks of coarse gravel and sand usually grass-grown and offering little opportunity for examination. Near Coldgate Mill the deposits abut against porphyrites, just below the 400 feet contour-line.

These sands and gravels form a plateau rising here and there into hummocks and ridges, ascending gradually to the 400 feet contour-line, where they abut against the porphyritic masses of Earle Hill, Whinnie Hill, etc. These hills are all divided by valleys, sometimes dry, below the 500 feet contour-line.

South Middleton to Lilburn.—Just below South Middleton is a dry valley through porphyrite, and like the majority of these valleys running north and south. Below this is moraine matter, which spreads out eastward, gradually assuming the characteristics of the water-worn gravels. Towards Lilburn is a long stretch of rolling country, over the surface of which rounded pebbles lie scattered.

The railway cuts one of the hummocks above the 300 feet contour-line. The section about 25 feet above the railway level is obscured by the falling gravel and sand, but the pebbles are all well rounded and consist of quartz, porphyrite, sandstone, limestone, etc. A few of the fragments retain evidence of glacial striation.

From Kingston Dean to Roddam Dean and between the 400 and the 500 feet contour-lines gravels abut against a cliff of Old Red Sandstone conglomerate. At the entrance to Roddam Dean the following section is exposed for a length of about 85 feet:—

(*a*) 2 feet, fine gravel.
(*b*) 22 feet, sand.
(*c*) 8 feet, coarse gravel, with occasional washings of reddish-brown sand. The gravel is composed chiefly of arenaceous rock, carbonaceous matter, quartz, ironstone, porphyrite, and Carboniferous Limestone.

The largest boulder in this section measured 2 feet in girth. Some of the gravel is cemented together, the cementing medium being iron oxide. Fossils of Carboniferous Limestone and glacially striated boulders occur.

South of Roddam Dean, and between the Roddam Dean conglomerates on the north and porphyrites on the south, is a large tract covered with sand and gravel, forming hummocks and ridges, with kettle-holes. The highest reach to the 400 feet contour-line. One of them, just below Wooperton Dean, evidently another ancient valley, is a kame-like ridge, about 800 feet in length, formed of coarse gravel and sand, the former varying from small pebbles no bigger than a pea to masses 27 inches in girth.

The ridge rises some 45 feet above its base. The materials are of sandstone, porphyrite, granite (Cheviot), tuff, and conglomerate from the north of Cheviot, and are rounded or subangular. The mass resembles that occurring below South Middleton. A pit a few yards away contains sand with very few pebbles.

Between Wooperton Dean and Brandon Dean is another ridge resembling the one just described. The two tiny streams occupy a valley once continuous, uniting the Breamish and Roddam Burn Valleys. Here, too, the debris passes downwards, and the sands and gravels are spread out over the 300 feet contour, where, however, they are all undoubtedly water-worn.

Recent Deposits.—A large area is covered with the alluvium of the Till and its tributary streams. This consists of loam, sand, and gravel. Most of the streams are still liable to flood, but evidently at some period, probably before the ice had finally disappeared from the greatest elevations, the dimensions of the swollen streams must have been prodigious, consequently much more of the valleys were submerged than now. The expansion of the alluvial deposits between Hedgeley and Wooperton may be the site of an old lake. The Randy Burn has an erratic course through a yellow and sometimes whitish clay, resembling that seen below the peat in other lake-basins, and covered with gravel and peaty soil. Another large alluvial plain exists south of the Lilburn near Ilderton Station. Old alluvial terraces may be seen at Brandon and Branton.

Occasionally amongst the sands and gravels are depressions, the

sites of former small lakes, now containing peat lying upon a yellow or whitish clay. In each case streams run through the hollows, and by diverting the courses of these much former bog land has been reclaimed and is now under cultivation.

Near Wooperton the Roddam Burn cuts through a section in which a bed of peat about 2 feet thick rests upon a yellowish-white clay, and is covered by a thick deposit of fine sand. The same section is continued on the other side of the railway, and from the form of the depression the lake must have been at least three-quarters of a mile in length. The depression is entirely surrounded by kame-like ridges of sand and gravel rising to the 300 feet contour-line.

At Lilburn is a large depression, surrounded by sands and gravels, containing peat in its lowest part, and surrounded by a tract of peaty soil. It is drained by a small stream running right through the peat and across the flat lake-like basin, where its channel has been diverted. A smaller lake, probably connected with this one, lies to the east, near Lilburn Grange.

North of Glanton Pike is a cup-shaped hollow representing another ancient lake-basin. It is surrounded by sands and gravels at the foot of Glanton Pike and a porphyritic offshoot of the Cheviots. Within this is a considerable thickness of peat surrounded by a tract of peaty soil. This basin is drained by the Powburn.

South of the Lilburn and just below Lilburn South Steads is another of these peat-covered tracts. This partakes more of the nature of a bog than a lake, and may have been flooded by overflow water from the Lilburn through a narrow channel which connects it with that stream.

At the head of Kingston Dean below the village of Ilderton two small streams unite and enclose near their junction a triangular-shaped area of peat. The valley, a deep trench through Old Red Sandstone conglomerate, is narrow, and the lake thus formed must have been of very limited dimensions.

Another lake-basin is above North Middleton, and a smaller deposit of peat, Cresswell Bog, opposite Haugh Head, Wooler, in which skeletons of the red deer were found in 1830, represents an overflow basin of the Wooler Water.

Conclusions.—The sections show that the sands and gravels were deposited under water, and the false and irregular bedding seems to indicate rapid deposition. The material, though to a large extent derived from the immediate neighbourhood, includes many rocks that are foreign. The source of supply of this material is readily found when we recognize the source of the drift on the flanks of the Cheviots and the moraine matter in the dry valleys with which these lower sands and gravels are connected. The debris is derived partly from local rocks and partly from foreign erratics left by ice-streams which overran the Cheviots from the north and south-west. The rivers together with water flowing through the present dry valleys fed from the glaciers and glacial lakes at higher altitudes, carried with them the moraine matter, rolling and rounding the rock fragments in their torrents, yet not quite obliterating all evidences of their glacial origin. These streams flowing into the same valley at the foot of the hills must have

contained a tremendous volume of water, which being confined by the Carboniferous ranges in the east and probably dammed by ice on the north would fill the channel to a considerable depth. The 500 feet contour-line was well above the line of principal lake-deposition, and probably the 400 feet line or a line between this and 300 feet limited the margin of the lake or series of lakes. The deposits at the higher elevations, while continuous with those confined to the 300 feet contour limit, are undoubtedly composed of material less water-worn. The coarse gravels in the sections near Wooler and Roddam were the littoral deposits, while the finer material and sands of Hedgeley were carried into the quiet and deeper portion of the lake.

The alluvial tracts of the Breamish and other streams, the peat and marl-like deposits of the recent lake-basins were formed after the supply of water to the mountain torrents had diminished but was still very much in excess of their present supply.

EXPLANATION OF PLATE XXXV.

FIG. 1. The Breamish Valley below Low Hedgeley. In the foreground, rising above the alluvial plain, are deposits of sand. The Carboniferous ridges are seen in the distance.

FIG. 2. Section of sand and gravel exposed by Wooler Water near Haugh Head, Wooler.

## V.—THE GEOLOGY OF THE TITTERSTONE CLEE HILLS.[1]

By E. E. L. DIXON, B.Sc., A.R.C.S., F.G.S.

THE following is a preliminary account of the rocks overlying the Lower Old Red Sandstone of the Titterstone Clee Hills, Shrops.

| | |
|---|---|
| Sedimentary Series . . | 4. Coal-Measures. |
| | 3. Millstone Grit (so-called). |
| | 2. Carboniferous Limestone Series. |
| | 1. Upper Old Red Sandstone. |
| Intrusive rocks . . . | Dolerite. |

1. The Upper Old Red Sandstone, consisting largely of sandy and pebbly beds, is fixed in age by its fish-fauna, which has long been known. Its junction with the underlying Lower Old Red marls is perfectly sharp, and probably marks an unconformity. Upwards, however, the group passes into—

2. The Carboniferous Limestone Series. The correlation of the local development with the Avonian of other districts has been sketched by Dr. Vaughan,[2] whose chief conclusion, that the highest recognizable horizon is little, if at all, higher than the upper part of the Zaphrentis Zone, holds good throughout the outcrops. That part of the series which overlies this horizon is so thin that it is difficult to believe that the top is much younger, even after making allowance for the fact that it consists of such shallow-water deposits that its rate of deposition must have been conditioned by the rate of subsidence of the sea-bottom. This conclusion as to age is supported by the age and relations to the local 'Millstone Grit' of the top of the Carboniferous Limestone Series in the Forest of Dean and the Bristol area (*op. cit.*).

[1] Abstract of paper read at the British Association, Sheffield, September, 1910.

[2] Quart. Journ. Geol. Soc., vol. lxi, pp. 252–4, 1905.

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Fig. 1. The Breamish Valley below Low Hedgeley.
„ 2. Section exposed by Wooler Water near Haugh Head, Wooler.

3. The 'Millstone Grit', which consists largely of sandstones and conglomerates, is undoubtedly conformable with the Carboniferous Limestone Series; and, as regards its base, is probably, from what has just been said, of Syringothyris age, and therefore much older than the Millstone Grit proper. Unfortunately its marine fossils, found at but one horizon, are of no zonal value, but its plants, from various levels, connect it, according to Dr. Kidston, with Lower Carboniferous rocks, not with the Millstone Grit proper. The conclusion as to the age of the lower part may therefore extend to the whole, and it is suggested that a non-committal place-name be applied to this formation instead of 'Millstone Grit'.

4. The Coal-measures include 'sweet', i.e. non-sulphurous, coals at several horizons from the base upward, and have yielded, besides a fairly rich flora, a small marine fauna at one or two horizons. The most important point, however, is the fact that they are not conformable with the 'Millstone Grit'. Their relationship has been revealed in a quarry, where their basal bed, a pebbly sandstone, rests at a low inclination and with marked discordance on evenly-dipping beds of Grit; and it affords the only satisfactory explanation of a transgression of the Measures across the outcrops of the Grits, which is brought out by 6 inch mapping.

As the 'Millstone Grit' is in part much older than the rocks of that name which underlie Coal-measures elsewhere, it becomes of interest to inquire whether the break between it and the Coal-measures on Clee Hill corresponds merely to the period of the Millstone Grit proper, or whether it includes some part of Coal-measure time also. That is, what is the age of the base of the Coal-measures on Clee Hill?

A feature of these measures is the presence in them of red clays and green sandstones of 'espley' type at intervals from a few feet above the base upward. According to Dr. Walcot Gibson rocks of these characters are not known in Coal-measures of other parts of England and Wales from any horizon lower than the Etruria Marls or a short distance below. Stratigraphical evidence also suggests that the Coal-measures of Clee Hill commence at this level. For there is no doubt, as has been pointed out by Mr. Daniel Jones, but that the Clee Hill measures are of the same horizon as the 'sweet coal series' of the adjacent Forest of Wyre Coal-field. There, in the Kinlet district, the junction of this series with the overlying sandstones which yield the 'sulphur coals' was found, in the course of an extension of the work to that neighbourhood, to be a conformable one; and therefore, as the sandstones have been recognized by Dr. Gibson and Mr. T. C. Cantrill as representing the Newcastle-under-Lyme Series, we may conclude that the 'sweet coal series' which, like the Clee Hill measures, include some red clays and 'espley'-like sandstones, corresponds to part of the Etruria Marls. It may be added that the most recent Coal-measures on Clee Hill are sandstones resembling the Newcastle Series of the Forest of Wyre, but too thin (they form an outlier of a few acres extent) and poorly exposed to yield further evidence of their age and relationships.

Against the conclusion that the Clee Hill measures commence with a representative of the Etruria Marls it may be urged that the latter

in their typical development[1] yield neither coal-seams nor the flora and fauna which have been obtained on Clee Hill. Similar coals, however, occur elsewhere in England and Wales at intervals up to much higher horizons, though not in association with the typical Etruria Marl rock-facies. The objection based on the flora is of greater weight, for Dr. Kidston finds that the plants are Middle Coal-measure forms, and therefore suggestive of a horizon lower than the Etruria Marls. But it may be remarked that the flora of the Blackband Group immediately below the Etruria Marls—the latter yield but rare plants—include no forms which do not occur in the Middle Coal-measures below.[2] The fauna of the marine bands is unfortunately of no horizonal value, though it includes a *Productus* which Dr. Vaughan finds closely resembles a form (*P.* aff. *scabriculus*, Mart.) abundant in the Avon section and elsewhere at the top of the Dibunophyllum Zone.

Finally, a consideration of the thicknesses and characters of the sedimentary series and of the outcrops of dolerite shows that earth-movements along a N.E.–S.W. line have made themselves felt during—

1. Upper Old Red Sandstone and Lower Carboniferous times.
2. Some period between Lower Carboniferous and Coal-measure times. (The latter movement has resulted in the unconformity between the 'Millstone Grit' and the Coal-measures.)

And further that the dolerite came up through several passages, some of which form a linear series having approximately this trend also.

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## VI.—The Origin of the British Trias.[3]

By A. R. Horwood,
Leicester Museum.

As a result of an investigation covering the Midland area, and especially from a study of the Upper Keuper of Leicestershire, the author, who has been aided in this research by a grant from the Government Grant Committee of the Royal Society, has arrived at the conclusion that, in so far as Great Britain is concerned, the Trias was laid down under delta conditions, during which, as in the Nile area to-day, æolian action took place, but was not responsible for deposition except locally on a small scale, and following the prevalent wind course.

The premises upon which this view is based are as follows:—

1. There is a continuity of area of deposition during the Upper Carboniferous, Permian, and Triassic periods, and a relative homology between the different parts of each, i.e. the base of each is similarly coarser than the top, and each has a red phase ultimately.

2. There is a gradual gradation from coarse sediments to finer from below upwards, as in modern (and other fossil) deltas. For instance, pebbles predominate in the lower phase, coarse sandstones (with

[1] See Dr. W. Gibson, Quart. Journ. Geol. Soc., vol. lvii, pp. 251 et sqq., 1901.
[2] Dr. R. Kidston, Quart. Journ. Geol. Soc., vol. lxi, p. 318, 1905.
[3] Abstract of paper read at the British Association, Sheffield, September, 1910.

occasional pebbles) in the centre, and finer and finer marls succeed in the last phase, which becomes increasingly ferruginous, as it merges into the lake-phase of the delta period.

3. The oldest member of the series, the Bunter, is acknowledged to be a delta formation—as Professor Bonney showed many years ago—and there is no evidence for the discontinuity of the agency producing that mode of deposition.

4. The continuity of the Bunter and Keuper is an argument for the extension of delta conditions to the Keuper, some 'basement beds' being indistinguishable from the Bunter.

5. The general evidence of an oscillation of level in early Triassic times and of overlapping is a proof of aqueous agency. Coupled together these vertical and horizontal movements are more distinctive of fluviatile than lacustrine or marine conditions.

6. There is a close analogy between the contour or geographical configuration of the Trias (whether we consider concealed or exposed areas) and modern deltas, e.g. the Mississippi, with its dactyloid extensions beyond the head.

7. There is a distinct analogy between the regular alternations of pebbles or sand and marl and seasons of torrential rains and floods or drought; that is to say, one sort of sediment is brought down at one period of the year, another at another. This may be witnessed in modern accumulations such as those of the Nile or Mississippi, where floods occur. These alternations are due to overflow of banks where 'skerries' lie on the hilly grounds now, just as they did when they were deposited. The grey marl is heavier than the red, and deposits are arranged as in a diffusion column.

8. The coloration of the Trias is original; that is to say, the red colour, imparted by peroxide of iron, was deposited on sediments under water-level. But it is not continuous everywhere with the bedding. 'Catenary' bedding is thus illusory. In only one case has an anticlinal fold of red-coloured marl been noticed underlying a grey band, but, on the other hand, synclinal folds are not uncommon, as in catenary bedding, the grey (heavier) marl lying in the hollows.

9. The great thickness of the Bunter pebble beds is a proof of a subsiding area at the opening of the Trias and of conditions suitable to a gradually widening and deeper delta area.

Normally delta deposits lie at an angle of about 45 degrees with the river bed, but as they are deposited in a subsiding area these beds describe an angle of 45 degrees and *become horizontal*. Thus the absence of delta bedding (not everywhere, for it occurs in Bunter, Lower and Upper Keuper here and there) in the Trias is proof that it was deposited in a subsiding area.

The 'radial dip' around submerged areas is due to the 'angle of rest' which normally produces inclined beds. The winding of the course of a river like the Mississippi, producing wide alluvial plains, would account for the Red Marl being deposited much as in a lacustrine area.

10. There is evidence from analogy of the ferruginous nature of the Upper Coal-measures, Permian, and Trias of the delta origin of the red marls.

11. The present horizontality, the littoral or marginal dip around the hills (e.g. Charnwood Forest), with the south-easterly dip (as in the Coal-measures and Permian formation), is original.

Trias reaches a height of 880 feet on Bardon Hill and is apparently in situ. Hence the elevated tracts must have originally been under water.

Moreover, the following facts may be noted in connexion with submerged hills under the Triassic covering :—

(1) The Trias is horizontal away from the older hills, as at Hathern, Sileby, etc.

(2) It is horizontal within old gullies and fiords within the islandic area, as well as over 'saddlebacks' (anticlinal folds in older rocks, as at Longcliffe, Enderby), as at Groby, Swithland, Mount Sorrel.

(3) There is an absence of faults of any magnitude. A very slight one affects the Rhætics at Glen Parva. The older one at Bardon has no relation to the Trias.

(4) It occurs filling fissures at great heights, as at Siberia Quarry, Bardon Hill.

12. Only the sandstones or 'skerries' are rippled, not the marls, with ripples S.W. to N.E. in direction; that is, the ridges run N.W. by S.E. generally, the force moving the wind and wave thus coming from the south-west. This is to be noted all round Charnwood Forest.

13. The screes are very largely to the south-west of the submerged older rocks which they cover, and from which (as on sea-coasts dunes are formed with screes forming at the foot of cliffs) they are derived.

14. The sandstones thin out and disappear eastward (as in the Lower Keuper), the marls westward, and the sandstones or skerries are chiefly on present hilly ground (as in the past).

15. The surface features of the old elevated rocks are largely original, where not covered by the Trias. The crags of High Sharpley, Broombriggs, etc., are quite untouched. The structure of the older formation can be distinctly made out as at Hanging Rocks. Blackbrook is only an emptied Triassic fiord.

16. Desert conditions are confined to the marginal contact of the Red Marl with certain older rocks (chiefly syenites as at Croft and Mount Sorrel), and this occurs at the same level, indicating its merely local phase. Wind-polished rocks occur to the west and north of Castle Hill, Mount Sorrel.

17. There is an absence of desert conditions in the surrounding area, i.e. away from the old rocks. Only in one instance has an anticlinal fold of Red Marl, simulating a dune, been discovered, as at Sileby.

18. The beds of gypsum and rock-salt are continuous in a linear direction, and are horizontal, which must be due to aqueous depositions and brought about during the greater lagoon phase at the close of the epoch, or the contemporary marginal lagoon phase during the early period, of the delta formation.

19. There is a gradual gradation of the Keuper into the Rhætics and so into the Lias, marine conditions commencing with the Rhætics.

20. The source of the sediments is in a large measure correlated

with that of the Bunter, which was formed by a river coming from North-West Scotland.

21. There is a correspondence between the characteristics of the micropetrography of the Bunter, Keuper, and modern delta formations. The Leicestershire Trias shows signs of chemical action, the Nile delta of mechanical. The chemical composition of volcanic and metamorphic rocks locally argues a local as well as a distant source for the heavier minerals of the Keuper.

22. The evidence of the flora and fauna shows that there were provinces, and these were so arranged as to allow for the prevalence of delta conditions. The climate was moist and equable.

Finally, we conclude that there is nothing to prove that desert conditions did anything more than locally act upon the rocks mechanically, and to some extent chemically. *They had no part whatever in the work of deposition;* that is to say, they disintegrated the previous rocks (pre-Triassic). There is positive, direct, and accumulative evidence to prove that the Trias as a whole (and not the Bunter only) was the work of rivers which had continued to bring sediment in one form or another from the north-west of Britain or the north more or less continuously, under one condition or another, from the close of the marine phase of Lower Carboniferous (Mountain Limestone) times.

## NOTICES OF MEMOIRS.

I.—British Association for the Advancement of Science. Sheffield, 1910. Address by the Rev. Professor T. G. Bonney, Sc.D., LL.D., F.R.S., President.[1]

. . . . . .

I DO not propose, as you might naturally expect, to discuss some branch of petrology; though for this no place could be more appropriate than Sheffield, since it was the birthplace and the life-long home of Henry Clifton Sorby, who may truly be called the father of that science. This title he won when, a little more than sixty years ago, he began to study the structure and mineral composition of rocks by examining thin sections of them under the microscope. A rare combination of a singularly versatile and active intellect with accurate thought and sound judgment, shrewd in nature, as became a Yorkshireman, yet gentle, kindly, and unselfish, he was one whom his friends loved and of whom this city may well be proud. Sorby's name will be kept alive among you by the Professorship of Geology which he has endowed in your University; but, as the funds will not be available for some time, and as that science is so intimately connected with metallurgy, coal-mining, and engineering, I venture to express a hope that some of your wealthier citizens will provide for the temporary deficiency, and thus worthily commemorate one so distinguished.

[1] We regret that our limited space prevents the insertion of the full text of Professor Bonney's Address. Thus the statement of facts relating to the Drifts of Britain have been omitted, but the main arguments relating to the interpretation of the phenomena have been retained.

But to return. I have not selected petrology as my subject, partly because I think that the great attention which its more minute details have of late received has tended to limit rather than to broaden our views, while for a survey of our present position it is enough to refer to the suggestive and comprehensive volume published last year by Mr. A. Harker;[1] partly, also, because the discussion of any branch of petrology would involve so many technicalities that I fear it would be found tedious by a large majority of my audience. . . . I purpose, then, to ask your attention this evening to some aspects of the glacial history of Western Europe.

. . . Much light will be thrown on this complex problem by endeavouring to ascertain what snow and ice have done in some region which, during the Glacial Epoch, was never submerged, and none better can be found for this purpose than the European Alps.

. . . . . .

In certain mountain regions, especially those where strong limestones, granites, and other massive rocks are dominant, the valleys are often trench-like, with precipitous sides, having cirques or corries at their heads, and with rather wide and gently sloping floors, which occasionally descend in steps, the distance between these increasing with that from the watershed. Glaciers have unquestionably occupied many of these valleys, but of late years they have been supposed to have taken a large share in excavating them. In order to appreciate their action we must imagine the glens to be filled up and the district restored to its former condition of a more or less undulating upland. As the mean temperature[2] declined snow would begin to accumulate in inequalities on the upper slopes. This, by melting and freezing, would soften and corrode the underlying material, which would then be removed by rain and wind, gravitation, and avalanche. In course of time the hollow thus formed would assume more and more the outlines of a corrie or a cirque by eating into the hillside. With an increasing diameter it would be occupied, as the temperature fell, first by a permanent snow-field, then by the *névé* of a glacier. Another process now becomes important, that called 'sapping'. While ordinary glacier-scour tends, as we are told, to produce "sweeping curves and eventually a graded slope", 'sapping' produces "benches and cliffs, its action being horizontal and backwards", and often dominant over scour. The author of this hypothesis[3] convinced himself of its truth in the Sierra Nevada. . . . Beneath the *névé* the temperature would be uniform, so its action would be protective, except where it set up another kind of erosion, presently to be noticed; but in the chasm, we are informed, there would be, at any rate for a considerable part of the year, a daily alternation of freezing and thawing. Thus the cliff would be rapidly undermined and be carried back into the mountain slope, so that before long the glacier would nestle in a shelter of its own making. Farther down the valley the

[1] *The Natural History of Igneous Rocks*, 1909.

[2] In the remainder of this Address 'temperature' is to be understood as mean temperature. The Fahrenheit scale is used.

[3] W. D. Johnson, *Science*, N.S., vol. ix, pp. 106, 112, 1899.

moving ice would become more effective than sub-glacial streams in deepening its bed; but since the *névé*-flow is almost imperceptible near the head, another agency must be invoked, that of 'plucking'. The ice grips, like a forceps, any loose or projecting fragment in its rocky bed, wrenches that from its place, and carries it away. The extraction of one tooth weakens the hold of its neighbours, and thus the glen is deepened by 'plucking', while it is carried back by 'sapping'. Streams from melting snows on the slopes above the amphitheatre might have been expected to co-operate vigorously in making it, but of them little account seems to be taken, and we are even told that in some cases the winds probably prevented snow from resting on the rounded surface between two cirque-heads.[1] As these receded, only a narrow neck would be left between them, which would be ultimately cut down into a gap or 'col'. Thus a region of deep valleys with precipitous sides and heads, of sharp ridges, and of more or less isolated peaks is substituted for a rather monotonous, if lofty, highland.

The hypothesis is ingenious, but some students of Alpine scenery think more proof desirable before they can accept it as an axiom.

. . . . . .

But even if 'sapping and plucking' were assigned a comparatively unimportant position in the cutting out of cirques and corries, it might still be maintained that the glaciers of the Ice Age had greatly deepened the valleys of mountain regions. That view is adopted by Professors Penck and Brückner in their work on the glaciation of the Alps,[2] the value of which even those who cannot accept some of their conclusions will thankfully admit. On one point all parties agree—that a valley cut by a fairly rapid stream in a durable rock is V-like in section. . . . It is also agreed that a valley excavated or greatly enlarged by a glacier should be U-like in section. But an Alpine valley, especially as we approach its head, very commonly takes the following form. For some hundreds of feet up from the torrent it is a distinct V; above this the slopes become less rapid, changing, say, from 45° to not more than 30°, and that rather suddenly. Still higher comes a region of stone-strewn upland valleys and rugged crags, terminating in ridges and peaks of splintered rock, projecting from a mantle of ice and snow. The V-like part is often from 800 to 1000 feet in depth, and the above-named authors maintain that this, with perhaps as much of the more open trough above, was excavated during the Glacial Epoch. Thus the floor of any one of these valleys prior to the Ice Age must often have been at least 1800 feet above its present level. As a rough estimate we may fix the deepening of one of the larger Pennine valleys, tributary to the Rhone, to have been, during the Ice Age, at least 1600 feet in their lower parts. Most of them are now hanging valleys; the stream issuing, on the level of the main river, from a deep gorge. Their tributaries are rather variable in form; the larger as a rule being more or less V-shaped; the shorter, and especially the smaller, corresponding more with the upper part

[1] This does not appear to have occurred in the Alps.

[2] *Die Alpen im Eiszeitalter*, 1909.

of the larger valleys; but their lips generally are less deeply notched. Whatever may have been the cause, this rapid change in slope must indicate a corresponding change of action in the erosive agent. Here and there the apex of the V may be slightly flattened, but any approach to a real U is extremely rare. The retention of the more open form in many small, elevated recesses, from which at the present day but little water descends, suggests that where one of them soon became buried under snow, but was insignificant as a feeder of a glacier, erosion has been for ages almost at a standstill.

The V-like lower portion in the section of one of the principal valleys, which is all that some other observers have claimed for the work of a glacier, cannot be ascribed to subsequent modification by water, because ice-worn rock can be seen in many places, not only high up its sides, but also down to within a yard or two of the present torrent.

Thus valley after valley in the Alps seems to leave no escape from the following dilemma: Either a valley cut by a glacier does not differ in form from one made by running water, or one which has been excavated by the latter, if subsequently occupied, is but superficially modified by ice.

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Many lake-basins have been ascribed to the erosive action of glaciers. Since the late Sir A. Ramsay advanced this hypothesis numbers of lakes in various countries have been carefully investigated and the results published, the most recent of which is the splendid work on the Scottish lochs by Sir J. Murray and Mr. L. Pullar.[1] . . . Even these latest researches have not driven me from the position which I have maintained from the first—namely, that while many tarns in corries and lakelets in other favourable situations are probably due to excavation by ice, as in the mountainous districts of Britain, in Scandinavia, or in the higher parts of the Alps, the difficulty of invoking this agency increases with the size of the basin—as, for example, in the case of Loch Maree or the Lake of Annecy—till it becomes insuperable. Even if Glas Llyn and Llyn Llydaw were the work of a glacier, the rock-basins of Gennesaret and the Dead Sea, still more those of the great lakes in North America and in Central Africa, must be assigned to other causes.

I pass on, therefore, to mention another difficulty in this hypothesis—that the Alpine valleys were greatly deepened during the Glacial Epoch—which has not yet, I think, received sufficient attention. From three to four hundred thousand years have elapsed, according to Penck and Brückner, since the first great advance of the Alpine ice. One of the latest estimates of the thickness of the several geological formations assigns 4000 feet[2] to the Pleistocene and Recent, 13,000 to the Pliocene, and 14,000 to the Miocene. If we assume the times of deposit to be proportional to the thicknesses, and adopt the larger figure for the first-named period, the duration of the Pliocene would

[1] *Bathymetrical Survey of the Scottish Freshwater Lochs*, by Sir J. Murray and Mr. L. Pullar, 1910.

[2] I have doubts whether this is not too great.

be 1,300,000 years, and of the Miocene 1,400,000 years. To estimate the total vertical thickness of rock which has been removed from the Alps by denudation is far from easy, but I think 14,000 feet would be a liberal allowance, of which about one-seventh is assigned to the Ice Age. But during that age, according to a curve given by Penck and Brückner, the temperature was below its present amount for rather less than half (·47) the time. Hence it follows that, since the sculpture of the Alps must have begun at least as far back as the Miocene period, one-seventh of the work has been done by ice in not quite one-fifteenth of the time, or its action must be very potent. Such data as are at our command make it probable that a Norway glacier at the present day lowers its basin by only about 80 millimetres in 1000 years, a Greenland glacier may remove some 421 millimetres in the same time, while the Vatnajökul in Iceland attains to 647 millimetres. If Alpine glaciers had been as effective as the last-named, they would not have removed, during their 188,000 years of occupation of the Alpine valleys, more than 121·6 metres, or just over 397 feet; and as this is not half the amount demanded by the more moderate advocates of erosion, we must either ascribe an abnormal activity to the vanished Alpine glaciers, or admit that water was much more effective as an excavator.

We must not forget that glaciers cannot have been important agents in the sculpture of the Alps during more than part of Pleistocene times. That sculpture probably began in the Oligocene period; for rather early in the next one the great masses of conglomerate, called *Nagelfluh*, show that powerful rivers had already carved for themselves valleys corresponding generally with and nearly as deep as those still in existence. Temperature during much of the Miocene period was not less than 12° F. above its present average. This would place the snow-line at about 12,000 feet.[1] In that case, if we assume the altitudes unchanged, not a snow-field would be left between the Simplon and the Maloja, the glaciers of the Pennines would shrivel into insignificance, Monte Rosa would exchange its drapery of ice for little more than a tippet of frozen snow. As the temperature fell the white robes would steal down the mountain-sides, the glaciers grow, the torrents be swollen during all the warmer months, and the work of sculpture increase in activity. Yet with a temperature even 6° higher than it now is, as it might well be at the beginning of the Pliocene period, the snow-line would be at 10,000 feet; numbers of glaciers would have disappeared, and those around the Jungfrau and the Finster Aarhorn would be hardly more important than they now are in the Western Oberland.

But denudation would begin so soon as the ground rose above the sea. Water, which cannot run off the sand exposed by the retreating tide without carving a miniature system of valleys, would never leave the nascent range intact. The Miocene Alps, even before a patch of

[1] I take the fall of temperature for a rise in altitude as 1° F. for 300 feet, or, when the differences in the latter are large, 3° per 1000 feet. These estimates will, I think, be sufficiently accurate. The figures given by Hann (see for a discussion of the question, Report of Brit. Assoc., 1909, p. 93) work out to 1° F. for each 318 feet of ascent (up to about 10,000 feet).

snow could remain through the summer months, would be carved into glens and valleys. Towards the end of that period the Alps were affected by a new set of movements, which produced their most marked effects in the northern zone from the Inn to the Durance. The Oberland rose to greater importance; Mont Blanc attained its primacy; the massif of Dauphiné was probably developed. That, and still more the falling temperature, would increase the snow-fields, glaciers, and torrents. The first would be, in the main, protective; the second, locally abrasive; the third, for the greater part of their course, erosive. No sooner had the drainage system been developed on both sides of the Alps than the valleys on the Italian side (unless we assume a very different distribution of rainfall) would work backwards more rapidly than those on the northern. Cases of trespass, such as that recorded by the long level trough on the north side of the Maloja Kulm and the precipitous descent on the southern, would become frequent. In the Interglacial episodes—three in number, according to Penck and Brückner, and occupying rather more than half the epoch—the snow and ice would dwindle to something like its present amount, so that the water would resume its work. Thus I think it far more probable that the V-like portions of the Alpine valleys were in the main excavated during Pliocene ages, their upper and more open parts being largely the results of Miocene and yet earlier sculpture.

During the great advances of the ice, four in number, according to Penck and Brückner,[1] when the Rhone glacier covered the lowlands of Vaud and Geneva, welling on one occasion over the gaps in the Jura, and leaving its erratics in the neighbourhood of Lyons, it ought to have given signs of its erosive no less than of its transporting power. But what are the facts? In these lowlands we can see where the ice has passed over the Molasse (a Miocene sandstone); but here, instead of having crushed, torn, and uprooted the comparatively soft rock, it has produced hardly any effect. The huge glacier from the Linth Valley crept for not a few miles over a floor of stratified gravels, on which, some 8 miles below Zurich, one of its moraines, formed during the last retreat, can be seen resting, without having produced more than a slight superficial disturbance. We are asked to credit glaciers with the erosion of deep valleys and the excavation of great lakes, and yet, wherever we pass from hypotheses to facts, we find them to have been singularly inefficient workmen!

I have dwelt at considerable, some may think undue, length on the Alps, because we are sure that this region from before the close of the Miocene period has been above the sea-level. It accordingly demonstrates what effects ice can produce when working on land.

In America also, to which I must now make only a passing reference, great ice-sheets formerly existed: one occupying the district west of the Rocky Mountains, another spreading from that on the north-west of Hudson's Bay, and a third from the Laurentian hill-country. These two became confluent, and their united ice-flow covered the region of the Great Lakes, halting near the eastern coast a little south

[1] On the exact number I have not had the opportunity of forming an opinion.

of New York, but in Ohio, Indiana, and Illinois occasionally leaving moraines only a little north of the 39th parallel of latitude. Of these relics my first-hand knowledge is very small, but the admirably illustrated reports and other writings of American geologists indicate that, if we make due allowance for the differences in environment, the tills and associated deposits on their continent are similar in character to those of the Alps.

In our own country and in corresponding parts of Northern Europe we must take into account the possible co-operation of the sea. In these, however, geologists agree that, for at least a portion of the Ice Age, glaciers occupied the mountain districts. Here ice-worn rocks, moraines and perched blocks, tarns in corries, and perhaps lakelets in valleys, demonstrate the former presence of a mantle of snow and ice. Glaciers radiated outwards from more than one focus in Ireland, Scotland, the English Lake District, and Wales, and trespassed, at the time of their greatest development, upon the adjacent lowlands. They are generally believed to have advanced and retreated more than once, and their movements have been correlated by Professor J. Geikie with those already mentioned in the Alps. Into that very difficult question I must not enter; for my present purpose it is enough to say that in early Pleistocene times glaciers undoubtedly existed in the mountain districts of Britain and even formed piedmont ice-sheets on the lowlands. On the west side of England, smoothed and striated rocks have been observed near Liverpool, which can hardly be due to the movements of shore-ice. . . . On the eastern side of England similar markings have been found down to the coast of Durham, but a more southern extension of land ice cannot be taken for granted. In this direction, however, so far as the tidal valley of the Thames, and in corresponding parts of the central and western lowlands, certain deposits occur which, though to a great extent of glacial origin, are in many respects different from those left by land ice in the Alpine regions and in Northern America.

They present us with problems the nature of which may be inferred from a brief statement of the facts.[1]

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(*To be concluded in our next Number.*)

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II.—British Association for the Advancement of Science, Eightieth Annual Meeting, held at Sheffield, September 1–7, 1910. List of Titles of Papers read in Section C (Geology) and in other Sections bearing upon Geology.

Presidential Address by *Dr. A. P. Coleman, F.R.S.*

*Cosmo Johns.*—The Yoredale Series and its equivalents elsewhere.

*Dr. J. E. Marr, F.R.S., & W. G. Fearnsides, M.A.*—The Palæozoic Rocks of Cautley (Sedbergh).

*Miss G. R. Watney & Miss E. G. Welch.*—The Graptolitic Zones of the Salopian Rocks of the Cautley Area (Sedbergh).

*Professor J. Joly, D.Sc., F.R.S.*—Pleochroic Halos.

[1] See footnote on p. 463, at the commencement of the President's Address.

*Dr. J. D. Falconer.*—Outlines of the Geology of Northern Nigeria.
*Dr. F. H. Hatch.*—The Geology of Natal.
*Cosmo Johns.*—The Geology of the Sheffield District.
*Professor A. McWilliam.*—The Metallurgical Industries in relation to the Rocks of the District.
*T. Sheppard.*—The Humber during the Human Period.
*Dr. Tempest Anderson.*—Matavanu, a new Volcano in Savaii (German Samoa).
*Rev. E. C. Spicer, M.A.*—On present Trias Conditions in Australia.
*Dr. Wm. H. Hobbs.*—Some considerations concerning the Alimentation and the Losses of existing Continental Glaciers.
*Dr. J. Milne, F.R.S.*—Seismological Report.
*Mrs. M. M. Ogilvie Gordon, D.Sc.*—Thrust Masses in the Western District of the Dolomites.
*Professor J. W. Gregory, D.Sc., F.R.S.*—On the Geology of Cyrenaica.
*Marmaduke Odling.*—An Undescribed Fossil from the Chipping Norton Limestone.
*Professor Edward Hull, LL.D., F.R.S.*—The Glacial Rocks of Ambleside.
*Dr. C. H. Lees, F.R.S.*—Mountain Temperatures and Radium.
*John Parkinson.*—Notes on the Geology of the Gold Coast.
*A. D. Hall, F.R.S., & Dr. E. J. Russell.*—The Objects and Scope of Soil Surveys.
*L. F. Newman.*—Drift Soils of Norfolk.
*C. T. Cimingham.*—The Teart Land of Somerset.
*Sir T. H. Holland, F.R.S.*—The Cause of Gravity Variations in Northern India.
Discussion on the concealed Coal-field of Notts, Derbyshire, and Yorkshire. Opened by *Professor P. F. Kendall, M.Sc., & Dr. Walcot Gibson.*
*H. Culpin.*—The Marine Bands in the Coal-measures of South Yorkshire.
*W. H. Dyson.*—The Maltby Deep Boring.
*Miss M. C. Stopes, D.Sc., Ph.D.*—Structural Petrifactions from the Mesozoic, and their bearing on Fossil Plant Impressions.
*Dr. L. Moysey.*—On some Rare Fossils from the Derbyshire and Notts Coal-field.
*A. R. Horwood.*—The Origin of the British Trias.
*Rev. A. Irving, D.Sc., B.A.*—On a Buried Tertiary Valley through the Mercian Chalk Range, and its later "Rubble Drift", etc.
*Cosmo Johns.*—The Geological Significance of the Nickel-Iron Meteorites.
*Ernest Dixon, B.Sc.*—The Geology of the Titterstone Clee Hills.
Reports on—
Erratic Blocks.
Crystalline Rocks of Anglesey.
Faunal Succession in the Carboniferous Limestone.
Critical Sections in the Palæozoic Rocks.
Charnwood Rocks.
Rocks of Glensaul.
Correlation and Age of South African Strata.

Geological Photographs.
Fossil Flora and Fauna of the Midland Coal-fields.
Topographical and Geological Terms used locally in South Africa.
*Dr. A. Irving, D.Sc., B.A.*—The pre-Oceanic Stage of Planetary Development.

List of Titles of papers read in other Sections bearing upon Geology :—

Section A.—Physical Science.

*Sir Norman Lockyer, K.C.B.*—Chemistry of the Stars.

Section E.—Geography.

*O. G. S. Crawford.*—A Regional Survey of the Andover District.
*J. Cossar.*—A Regional Survey of Midlothian.
*H. Brodrick.*—The Underground Waters of the Castleton District.
*Dr. C. A. Hill.*—Further Exploration in the Mitchelstown Cave.

Section H.—Anthropology.

Presidential Address by *W. Crooke, B.A.*
*A. M. Woodward & H. A. Ormerod.*—A Primitive Site in South-West Asia Minor.
*A. J. B. Wace & M. S. Thompson.*—Excavations in Thessaly.
*Professor R. C. Bosanquet.*—The work of the Liverpool Committee for Excavation and Research in Wales and the Marches.
*Professor W. M. Flinders Petrie.*—The Excavations at Memphis.
*Dr. C. G. Seligmann.*—On a Neolithic Site in the Southern Sudan.
*Dr. T. Ashby.*—Excavations at Hagiar Kim and Mnaidra, Malta.
*H. D. Acland.*—Prehistoric Monuments in the Scilly Isles.
*Alexander Sutherland.*—On the Excavation of the Broch of Cogle, Watten, Caithness.
*G. Clinch.*—Unexplored Fields in British Archæology.
Report of a Committee to investigate the Lake Villages in the neighbourhood of Glastonbury.
Report of a Committee to ascertain the Age of Stone Circles.
*Rev. Dr. Irving.*—On a Prehistoric Horse found at Bishop's Stortford.

Section K.—Botany.

*Professor F. O. Bower.*—Semi-popular lecture on Sand-dunes and Golf-links.
*Professor F. O. Bower.*—On two Synthetic Genera of Filicales.
*Professor D. T. Gwynne-Vaughan.*—On the Fossil genus *Tempskya*.
*Dr. M. C. Stopes.*—Further Observations on the Fossil Flower.

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Abstracts of Papers read in Section C (Geology) at the Meeting of the British Association for the Advancement of Science, Sheffield, September 1, 1910.

## III.—The Coal-measures of the Concealed Yorkshire, Nottinghamshire, and Derbyshire Coal-field. By Walcot Gibson, D.Sc.

On the map accompanying Mr. Currer Brigg's Report on District D in the Final Report of the Royal Commission on Coal Supplies for 1905 a triangular area having its apex at the Haxey (South Carr)

boring is marked off as the proved extent of the concealed coal-field. The area thus defined amounts to about 460 square miles. To this, as the result of information obtained from several borings for coal completed since 1905, there can be added about 200 square miles situated north-east of Haxey and about 200 square miles lying south-east of Haxey. Much information has also been collected in the proved coal-field. The new material, so far as it relates to the Coal-measures, may be considered under (1) shape of the Palæozoic floor, (2) character of the measures, (3) the workable seams that are likely to occur within 4000 feet depth, and (4) their probable extension beyond the limits considered as proved in the Report of 1905.

1. *Palæozoic Floor.*—Between the outcrop of the Magnesian Limestone and the River Trent, north of Nottingham, the Permian rests on a uniform plain with a slope not exceeding two degrees and having a general direction to the east or a little north of east. Over the faulted area, south of Nottingham, the uniformity of slope has been broken; but outside the faulted belt the same even surface is maintained between Ruddington, Edwalton, and Owthorpe.

2. *Character of the Measures.*—The Barlow (Selby) boring in the north, the Thorne boring in the east, and that of Owthorpe in the south show that the Coal-measures immediately beneath the newer formations belong to an horizon several hundred feet above the Top Hard or Barnsley Coal, which is a high and most valuable seam in the coal-field. In these measures a marine band (20 to 50 feet thick) lies between 520 feet (Oxton boring) and 629 feet (Mansfield Colliery) above the Top Hard Coal in Nottinghamshire, and, as ascertained by Mr. Culpin at Brodsworth and Bentley and by Mr. Dyson at Maltby, between 670 and 705 feet above the Barnsley Coal in Yorkshire. The fauna, exclusively marine, is represented by fifty species distributed among thirty-seven genera. Many of the forms occur in the shales below the Millstone Grits, and a few represent survivors from the Carboniferous Limestone. The persistence, thickness, and fauna of the bed indicate a general and a fairly prolonged incursion of the open sea during late Middle Coal-measures. Minor incursions are represented by a few thin beds occurring above and below this horizon in Nottinghamshire and Yorkshire. The thickness of the measures as a whole increases to the north and diminishes to the east.

3. *The Workable Seams.*—All the borings and sinkings strike Coal-measures above the chief marine bed; but, except at Oxton and Maltby, both situated in the proved coal-field, the Upper Coal-measures have been completely removed by pre-Permian denudation. The seams above the Top Hard Coal and Barnsley Coal are irregular in their occurrence and of uncertain quality. In the Doncaster and Thorne area the Dunsil Coal 50 feet below the Barnsley bed appears to be a valuable seam, but it deteriorates south of Doncaster. Most of the lower coals over the recently proved extension of the coal-field lie beyond the limit of profitable working. The future resources of the coal-field therefore mainly depend upon the thickness, quality, and depth of the Top Hard or Barnsley Coal.

4. *Extension.*—As a result of the explorations made since the Report of 1905 the proved limit of the concealed coal-field may with some

confidence be extended to a line joining Selby, Thorne, Haxey, and Owthorpe, but the quality and thickness of the coal cannot be foretold. There is no conclusive evidence to show whether, north of Thorne, the Barnsley Coal will take on the inferior character which it assumes north-east and east of Wakefield under the name of the Warren House Coal, and whether the thinning out of the Top Hard Coal observable in some of the collieries south of Mansfield will continue to the east.

A further extension north of the Ouse, east of the Trent, and south-east of Owthorpe is probable, but it is important to bear in mind how much there must be of conjecture in any conclusions arrived at from the slender evidence at present available.

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IV.—The Graptolitic Zones of the Salopian Rocks of the Cautley Area near Sedbergh, Yorkshire. By Miss G. R. Watney and Miss E. G. Welch.

WE have obtained the following zones in the Ludlow Rocks in descending order:—

| | | |
|---|---|---|
| 1. | *Monograptus leintwardinensis* (Hopk.) | Lower Bannisdale Slates. |
| 2. | *Monograptus Nilssoni* (Barr.) | Coniston Grits. / U. Coldwell Beds. |
| 3. | *Monograptus vulgaris* (Wood) | M. Coldwell Beds. |

In the Wenlock the following zones have been found in descending order:—

| | | |
|---|---|---|
| 1. | *Cyrtograptus Lundgreni* (Tullb.) | L. Coldwell Beds. / Brathay Flags. |
| 2. | *Cyrtograptus Linnarssoni* (Lapw.) / *Cyrtograptus symmetricus* (Elles) | Brathay Flags. |
| 3. | *Monograptus riccartonensis* (Lapw.) | Brathay Flags. |
| 4. | *Cyrtograptus Murchisoni* (Carr) | Brathay Flags. |

These zones are comparable with those discovered by Miss Elles[1] and Mrs. Shakespear[1] in Wales and the Welsh Borderland[1]; though we have not yet succeeded in finding all the zones which they record we hope shortly to establish them in this area.

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V.—Structural Petrifactions from the Mesozoic, and their bearing on Fossil Plant Impressions. By Miss M. C. Stopes, D.Sc., Ph.D., F.L.S.

THE paper dealt with the importance of the structural petrifactions in the Carboniferous, e.g. exposure of the true nature of so many supposed 'ferns'; with the need of similar petrifactions from beds of Mesozoic age; and the danger of inferences drawn from plant *impressions*, e.g. untrustworthiness of many of Heer's and Ettingshausen's systematic determinations.

The discovery of true petrifactions in the Cretaceous, the nature of the flora contained in the nodules, and unusual points in its composition were considered. Special illustrations of its interest are: *Yezonia*, a new type of which the external appearance gives no clue to its nature; the discovery of the first-known flower with its anatomy petrified; and of the internal anatomy of the leaves of *Nilssonia*, long well known as impressions.

[1] Q.J.G.S., 1900.

VI.—Notes on the Lower Palæozoic Rocks of the Cautley District, Sedbergh, Yorks. By J. E. Marr, Sc.D., F.R.S., and W. G. Fearnsides, M.A., F.G.S.

THE general succession is well known. The following additions to our knowledge of the various divisions have been recently obtained by us :—

*Salopian.*—Divisible into Lower Ludlow Rocks (Bannisdale Slates, Coniston Grits, and Coldwell Beds) above, and Wenlock Rocks (Brathay Flags) below. The calcareous gritty flags with *Phacops obtusicaudatus* are found here at the base of the Coldwell Beds, and form a ready line of separation between the Ludlow and Wenlock graptolitiferous strata. The Salopian graptolitic zones are being worked out by Miss G. R. Watney and Miss E. G. Welch.

*Valentian.*—The succession as described by one of us with the late Professor Nicholson was incomplete. We have now found a section in Watley Gill which nearly completes the sequence. In that beck the *Monograptus argenteus*, *M. fimbriatus*, and *Dimorphograptus* zones of the Skelgill Beds are found with their intercalated Trilobite beds, the higher graptolitic zones being absent owing to a fault which repeats the *Dimorphograptus* beds. The *argenteus* zone contains the type fossil and its usual associates, and exhibits the 'green streak' seen in the Lake District and in North Wales.

*Ashgillian.*—The Ashgill Shales have long been known here. The basal *Staurocephalus* Limestone appears to be represented by a greyish argillaceous limestone in Taith's Gill, which succeeds the Caradocian rocks with perfect conformity, and yields abundance of *Remopleurides radians* and other fossils; also by a similar limestone in the same position in Backside Beck, with badly preserved Trilobites, etc.

*Caradocian.*—Black calcareous shales with their argillaceous limestones containing a very rich Caradocian fauna, recalling that of the Trinucleus Shales of Sweden. The fauna is being worked at and separated from that of the Ashgillian Beds.

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VII.—On some Rare Fossils from the Derbyshire and Nottinghamshire Coal-field. By L. Moysey, B.A., M.B., B.C., F.G.S.

IN the temporary museum in connexion with this section there will be found a collection of fossils illustrating some of the rarer forms of the Coal-measure fauna obtained during the last eight years from this district. From these it has been thought desirable to select some, mainly fragmentary specimens, for more detailed description, in the hope that they may be of assistance in the identification of other more perfect specimens, should such be obtained, and that a discussion on their many perplexing features may lead to a more definite idea as to their affinities.

Specimen 1, from Shipley, near Ilkeston, Derbyshire. These minute bodies, about 3 mm. long, are evidently the valves of the carapace of a Phyllopod. A similar fossil was described by Lea[1] from Pennsylvania under the name of *Cypricardia leidyi*. Professor T.

[1] Proc. Acad. Nat. Sc. Philadelphia, vol. vii, pt. iv, p. 341, 1855.

Rupert Jones[1] gave it the name of *Leaia leidyi*, and described two varieties, one *L. leidyi* var. *Williamsoniana*, from Ardwick, near Manchester, and the other *L. leidyi* var. *Salteriana*, from Cottage Row, Crail, Fifeshire. The present example agrees fairly closely with the Fifeshire specimen; but, on the whole, it seems best to create a new species for it, *Leaia trigonoides*, sp. nov., rather than risk confusion by adding a varietal appellation.

Specimen 2, from Shipley, is of interest, owing to the great difficulty of its interpretation. Possibly the best explanation is that it is the glabellar region of a *Prestwichia*. The presence of two minute crescentic dots, one on each side of the median line, is in favour of this theory, on the assumption that they are the larval eyes of the animal. Dr. Henry Woodward, however, who has examined this specimen, is very doubtful as to its limuloid origin.

Specimen 3, from the Kilburn Coal, Trowell Colliery, Notts. The curious feature in this specimen is the presence of crescentic openings on each segment similar to the 'stigmata' found in scorpions and other Arachnids, suggesting that it may be a fragment of an air-breathing animal.

Specimen 4, from Shipley, is probably one of the first abdominal segments of *Eoscorpius* sp., two specimens of which genus have been found in this district—one from near Chesterfield, and another, at present undescribed, found by the author in the Digby Claypit, Kimberley, Notts.

Specimen 5, from Brindsley, Notts, is a single segment of an Arthropod, and possibly referable to *Eurypterus*.

Specimen 6, from Shipley, is the wing of an insect probably belonging to the order Palæodictyoptera of Scudder.

Specimens 7 and 8, also from Shipley, are a fragment of a much smaller insect's wing, which, in its incomplete state, would be impossible to assign to any definite order.

Insects' wings are very uncommon in the Coal-measures of this district, only one having been found near Chesterfield, and described by S. H. Scudder[2] under the name *Archæoptilus ingens*.

## REVIEWS.

### I.—A Great Catalogue of Books on the Natural Sciences.

British Museum (Natural History).—Catalogue of the Books, Manuscripts, Maps, and Drawings in the British Museum (Natural History). Vol. III. L–O. By Bernard Barham Woodward. 4to. London, 1910. pp. 1039–1494. Price £1 per volume.

In September, 1903, we had the pleasure to announce the publication of the first volume of this work from A–D. Volume II (E–K) followed in 1904, and progress since then has been seriously hampered

[1] Mon. Pal. Soc., 1862, Appendix, p. 115, pl. i, fig. 21, etc.

[2] S. H. Scudder, "Haxapod Insects of Great Britain": Mem. Boston Nat. Hist. Soc., vol. iii, pp. 217–18, 1873–94.

by the great increase in current library work common to all libraries. We are, however, thankful to receive Volume III, for now we are well past the middle of the work, and the whole cannot be much longer delayed. The present volume is even better than its predecessors, and in many points is better than anything of the kind that has been done before. The same wealth of bibliographic detail is observed whenever necessary, as may be seen under C. F. P. Martius, François Levaillant, and Martin Lister for example; the same intelligent and uniform rendering of Russian names is employed; and careful attention is called to many bibliographic subtilties, so puzzling to the lay mind. Full details of books of travel are given, as for instance under Middendorff, where the separate papers are properly listed out and the dates given, and exact dates are furnished (we believe for the first time) of such troublesome books as the Naturalist's Library, which was reprinted again and again as the supply ran short. That part of the Catalogue dealing with Linnæus is one of which any librarian might be proud. It is a *tour de force*, and was, we believe, issued specially as a separate for the celebration in honour of the great naturalist in Stockholm three years ago.

A brief Preface by Mr. Fletcher reminds us that Mr. Woodward has continued to profit by the assistance of his colleagues on the staff, his valued attendant Mr. Hadrill, his clerical assistant Mrs. Wilson, and other friends, but the inception and carrying through of this invaluable book is due to himself, and those who use it and recognize its utility can hardly find words to properly express their thanks to him. What the value of a Catalogue like this must be to those smaller libraries who can never hope to amass such a collection or to get access to such reference books whereby such a collection can be properly catalogued we do not know; all we hope is that the Trustees of the British Museum having issued such a book, librarians will avail themselves of the privilege and secure it.

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II.—The Earthquake of 1872 in the Owens Valley, California. By Professor W. H. Hobbs. Beiträge zur Geophysik, vol. x, pp. 352–85, 1910.

THE Owens Valley earthquake of March 26, 1872, is one of the greatest and most interesting of Californian earthquakes, and, in writing its history, Professor Hobbs has supplied a long-felt want, and supplied it well. The principal sources of his information are Whitney's almost inaccessible report published in 1872, from which he makes several interesting extracts, and the valuable maps and photographs of the fault-scarps obtained by Mr. Willard D. Johnson during his survey of the district in 1907. Though the natural tendency of fault-scarps formed during earthquakes is to lose their sharpness and eventually to become effaced, many of them are still recognizable. Those along which movements took place in 1872 run along the west side of the Owens Valley at the foot of the Alabama Hills for a total distance of about forty miles. For considerable distances, generally one or two miles, the individual scarps maintain

a nearly constant direction, but at intervals they are subject to abrupt changes of direction so as to form a series of zigzags with sharp elbows. In places the faults run in parallel lines, the ends overlapping for short distances. All scarps, which are not much worn away, are steeply inclined and appear to be the continuations of nearly vertical faults. The highest measured vertical displacement along any scarp is 23 feet. Abrupt variations, and even reversal in throw are, however, occasionally seen. Horizontal displacements were also observed, though the evidence of such displacements is now almost obliterated. One of 15 feet towards the north was measured by Gilbert eleven years after the earthquake, and another of 9 feet was photographed by Mr. Johnson.

C. D.

## III.—Brief Notices.

1. "The Sand-Dunes of the Libyan Desert" are described and illustrated by Mr. H. J. Llewellyn Beadnell (*Geograph. Journ.*, April, 1910). In his opinion the material has been derived from the arenaceous formations of post-Middle Eocene age that lie to the north. The dunes consist mainly of silica, but in places they contain rather more than 7 per cent. of limestone granules. As the author remarks, "In some localities extensive and prosperous settlements have been overwhelmed and blotted out of existence, while in others the sand and dust-laden winds have been of positive benefit to the inhabitants. In the south part of the oasis of Kharga, for instance, broad terraces of cultivable loam have been gradually built up in the neighbourhood of the wells, the deposition of the wind-borne material being encouraged on account of its valuable fertilizing properties." The subject is therefore of considerable economic importance as well as scientific interest. The author's observations show that the dunes progress steadily southwards at an average rate of 15 or 16 metres a year.

2. Landslides in the San Juan Mountains, Colorado, form the subject of a memoir by Mr. Ernest Howe (Professional Paper 67, U.S. Geol. Survey, Washington, 1907). It is well illustrated, and contains much information of general interest and importance.

The topography of the San Juan Mountains is described as "that of a dissected and glaciated plateau of more or less horizontally bedded volcanic rocks resting upon a foundation of sedimentary rocks". The oldest rocks, which are pre-Cambrian, are covered unconformably by various Palæozoic and Mesozoic formations, and by the Telluride conglomerate that is perhaps of Eocene age. The Tertiary volcanic rocks, with an aggregate thickness of "many thousands of feet" in the central part of the mountains, rest on the Telluride conglomerate or on a floor of older rocks, the dip of which is southerly, westerly, or northerly. Various forms of rock-falls, landslips, and soil-slips are described, all the rocks being liable to be affected. The superficial movements of the ground comprise earth-slides or soil-slips, mud-flows, and talus slumps. Other movements, though less common, are due to movement along bedding-planes in the direction of the dip. The primary jointing and secondary shattering of the rocks has led to

rock-falls. Further, the oversteepness of the valley-walls that existed in a great many places after the final retreat of the ice of the Glacial epoch has had a potent influence on landslides. Earthquakes in some instances have been the immediate cause of the breaking away of rock-masses.

The author draws particular attention to 'rock streams', which have certain features in common, both with landslides and ordinary talus. In general appearance these accumulations resemble long tongues or lobes of talus stretching far out from the base of the cliffs from which they were derived, over the nearly level or gently sloping floors of the glacial cirques. The deposits are usually bounded by a sharply defined steep front; their surfaces are marked by irregular hummocks or wave-like ridges; and the material consists of angular blocks of rock, averaging about one foot in diameter, with finer and coarser material. They characterize tracts where the rocks are much shattered. Ice and snow may have influenced the formation of these rock-streams, but the author "believes that they are strictly landslides and owe their present form entirely to the nature of their fall and to the character or physical condition of the rocks involved in the fall". They appear in the main to be due to the rapid slipping of surface material.

3. The Journal of Geology (Chicago) maintains its reputation for original essays on subjects of wide interest and importance. In the number for May–June, 1910, Mr. E. S. Bastin writes on the "Origin of the Pegmatites of Maine", and concludes that the broader field-relations suggest that the large areas characterized by pegmatite intrusions constitute in reality the roofs overlaying granite batholiths. Mr. S. R. Capps, jun., deals with the "Rock Glaciers in Alaska". These are formed of angular talus and occupy cirques, or the bottoms of cirque-like valleys, that were excavated at the time of the maximum glaciation of the region. Small glaciers still exist at the heads of some of the valleys, but in most cases conditions for ordinary glacial activity have ceased, the winter's snows having all melted away during the summer. The base of the talus, however, has been filled with interstitial ice, and the movement of the mass in a glacier-like way has continued. In some respects these 'rock glaciers' are allied to the 'rock streams' described by Mr. Ernest Howe as essentially due to surface landslides. In the number for July–August, Mr. H. M. Eakin contributes an article on "The Influence of the Earth's Rotation upon the Lateral Erosion of Streams"; and Mr. R. E. Hore writes "On the Glacial Origin of Huronian Rocks of Nipissing, Ontario".

4. American Philosophical Society.—In the Proceedings for January to April, 1910 (vol. xlix, pp. 57–129) there is an important memoir by Mr. W. H. Hobbs on "Characteristics of the Inland Ice of the Arctic Regions". The author contrasts the physical conditions of the North and South Polar areas, and the differences between mountain and continental glaciers. The ice-cap glacier, while of smaller dimensions than the true inland ice or the continental glacier, is regarded as distinctly allied with this type, having few affinities with mountain glaciers. Descriptions are given of the ice-cap glaciers of Norway and Iceland, of the ice-covered archipelago of Franz Josef

Land, of the inland ice of Spitzbergen, and of the continental glacier of Greenland. The englacial and subglacial drainage, the marginal lakes, the fresh water or 'submarine wells' in fiord heads, and the discharge of bergs, are likewise described; and the subject is well illustrated by diagrams and pictorial views.

In the number for July, 1910, Mr. W. J. Sinclair records the discovery of bones of *Paramylodon* in the Pleistocene asphalt deposits near Los Angeles. Mr. T. J. J. See gives the "Results of Recent Researches in Cosmical Evolution", believing that the planets were developed in the solar nebula, and that our moon was originally a planet which became a satellite, but was never part of the terrestrial globe.

5. We have received a copy of the sixth edition of the useful *Tables for the Determination of Minerals by Physical Properties*, by Dr. Persifor Frazer and Professor A. P. Brown. (London and Philadelphia, J. B. Lippincott Co., 1910.)

## CORRESPONDENCE.

### YORKSHIRE GEOLOGISTS AND EDITORS.

Sir,—Would the Hull Geological Society kindly inform us of what possible use it is to publish generic names under the combinations of letters quoted below?

| | | | |
|---|---|---|---|
| Psil. | Cor. | Ast. | Echi. |
| Cal. | Agas. | Nicro. | Der. |
| Schlot. | Arn. | Ambly. | Polym. |
| Ver. | Aric. | Oxyn. | Upt. |

We doubt whether one person in a hundred has the remotest idea what they mean. It is impossible for the Recorder to waste his time looking them up, and work presented in such a way can only be disregarded.

While in the critical mood we should also like to ask whether the table on the distribution of *Belemnites* in the Lias is the result of personal collecting or of collation of printed data? If the latter, it is of little value. If the former, it would be interesting to know who is the authority for the determination of Simpson's species. What really valuable work Yorkshire geologists might do if some competent man would go and draw and describe Simpson's types in the same way as Mr. Buckman is doing for the Ammonites!

Recorder.

### LYME REGIS CHURCH.

Sir,—The ancient and historic church of St. Michael, Lyme Regis, which is a good example of fifteenth century Perpendicular Gothic, is in danger owing to the encroachment of the sea. The cliffs of the district are of Blue Lias and crumble readily. Many can remember when two fields stretched between the churchyard and the edge of the